Technical Program

The Executive Committee reserves the right to amend the program if necessary.

Monday, 24 June

07:30 **Continental Breakfast in Exhibit Hall**

08:30 - 09:10 **Welcome Address**
General Chair: Christofer Hierold, *ETH Zürich, SWITZERLAND*

Technical Program Introduction
Program Chair: Jürgen Brugger, *École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND*

09:00 - 09:45 **Plenary Presentation I**

M1A.P01 HUMAN ORGANS-ON-CHIPS
Donald Ingber
Harvard University, USA, Harvard Medical School, USA, and Boston Children's Hospital, USA

I will discuss our work on the development of human Organ-on-a-Chip (Organ Chip) microfluidic culture devices lined by living human cells to replace animal testing, accelerate drug development, discover new biomarkers, and advance personalized medicine. Our Organ Chips are effectively living 3D cross sections of major functional units of living organs that contain human organ-specific epithelial cells interfaced with human microvascular endothelial cells that are exposed to fluid flow to mimic vascular perfusion. We also recreate the relevant physicochemical microenvironment of each organ, for example, by recreating breathing motions and an air-liquid interface in lung and trickling flow and peristalsis-like deformations in intestine. We have engineered multiple human Organ Chips, including lung (alveolus and airway), intestine (duodenum, ileum, colon), kidney (proximal tubule and glomerulus), bone marrow, liver, and blood-brain barrier (BBB) chips, as well as fluidically linked BBB Chips and brain neuronal network chips. This Organ Chips have been used to develop various human disease models and uncover new drug targets and potential clinical biomarkers, as well as discover new therapeutics. In addition, multiple different human Organ Chips have been fluidically linked to create an automated 'human Body-on-Chips' for real-time analysis of cellular responses to pharmaceuticals, chemicals, and toxins, as well as for quantitative in vitro-to-in vivo translation (IVIVT) of human drug pharmacokinetics in vitro.

09:45 - 10:00 **2019 IEEE Daniel E. Noble Award for Emerging Technologies Receipient**
Thomas W. Kenny
Stanford University, USA

10:00 - 10:15 **Transducers Early Career Award Presentation**

10:15 - 11:00 **Break and Exhibit Inspection**

Session M2A - Bio Microfluidics

11:00 - 11:15

M2A.001 DIGITAL DNA SEQUENCE PROFILING OF RARE EPIGENETIC CANCER BIOMARKERS IN A HIGHLY PARALLELIZED MICROFLUIDIC PLATFORM
Christine M. O'Keefe, Sixuan Li, and Tza-Huei Wang
Johns Hopkins University, USA

We design and construct a digital melt platform to trap DNA molecules at high efficiency in a microfluidic device and assess molecule-by-molecule methylation heterogeneity. We describe the microfluidic design and instrumentation for highly parallelized and efficient single molecule methylation profiling.

11:15 - 11:30

M2A.002 QUAD LIPID BILAYER MODULE WITH 1-GΩ SERIES RESISTORS TOWARD QUANTITATIVE STOCHASTIC-BIOSENSORS
Yoshihisa Ito[1], Toshihisa Osaki[2], Koki Kamiya[2], Tetsuya Yamada[2], Norihisa Miki[1], and Shoji Takeuchi[3]
[1]Keio University, JAPAN, [2]Kanagawa Institute of Industrial Science and Technology, JAPAN, and [3]University of Tokyo, JAPAN

Artificial cell membranes with membrane proteins can form sensitive/selective biosensors. But the sensors suffer lengthy detection time at low concentration of analytes because the sensing mechanism relies on stochastic phenomena. Here, we connected independent membrane sensors in parallel, where the current through the multiple membranes was monitored by a single detector. With this format, the detection time is shortened based on the number of the array and the sensing can be quantitative.

11:30 - 11:45

M2A.003 A SINGLE-CELL IMPEDANCE MICRO-CYTOMETER FEATURING 3D ELECTRO-FLUIDIC STRUCTURES MONOLITHICALLY INTEGRATED WITHIN SILVER PDMS
Chengwu Han[1], Ziheng Liang[2], Duli Yu[2], and Xiaoxing Xing[2]
[1]China-Japan Friendship Hospital, CHINA and [2]Beijing University of Chemical Technology, CHINA

This work for the first time demonstrates a single-cell impedance micro-cytometer with 3D differential electrodes and fluidic sidewalls completely made of silver-PDMS composites (AgPDMS). Such monolithically integrated electro-fluidic structure is an outcome of one-step molding from a readily used master, obviating extra sacrificial layer patterning as required in existing device incorporating AgPDMS electrodes.

11:45 - 12:00

M2A.004 A CONSTRICTION CHANNEL BASED MICROFLUIDIC FLOW CYTOMETRY ENABLING HIGH-THROUGHPUT QUANTIFICATION OF MULTIPLE TYPES OF INTRACELLULAR PROTEINS IN SINGLE CELLS

Lixing Liu, Beiyuan Fan, Hongyu Yang, Deyong Chen, Hua Wei, Guoqing Zhang, Junbo Wang, and Jian Chen
Chinese Academy of Sciences (CAS), CHINA

This paper presents a constriction channel based microfluidic flow cytometry enabling high-throughput quantification of multiple types of intracellular proteins from large populations (>10,000 cells for each cell type). This microfluidic flow cytometry can distinguish different cells isolated from multiple tumor types and paired tumor cells isolated from the same tumor type. This technique adds a new quantitative dimension to flow cytometry in single-cell analysis.

12:00 - 12:15

M2A.005 INTEGRATED PARALLEL FLOW CYTOMETRY DEVICE WITH TIME GATED SPADS

Daiki Sato[1], Takahiro Shindo[1], Takeshi Mitsunaka[1], Yoshihisa Fujimoto[1], Kunihiko Iizuka[1], Saori Tago[2], Yuki Takayama[2], Teruo Fujii[2], and Soo Hyeon Kim[2,3]
[1]Sharp Corporation, JAPAN, [2]University of Tokyo, JAPAN and [3]JST, PRESTO, Japan

We demonstrated parallelized detection of fluorescent microbeads flowing in multiple microfluidic channels coupled with an array of single photon avalanche diodes (SPADs). A CMOS integrated circuit containing SPAD array was used for time-domain separation of fluorescence from excitation light using fast gating and active quenching circuits to realize parallelized detection of fluorescence without complex optical systems. The system can be used for the development of parallelized flow cytometry.

12:15 - 12:30

M2A.006 MICROFLUIDIC ISOLATION OF APTAMERS FOR GLYCAN TARGETS

Timothy Olsen, Kyung-Ae Yang, Xin Meng, Milan N. Stojanovic, and Qiao Lin
Columbia University, USA

This paper demonstrates a microfluidic approach to isolate aptamers, single-stranded oligonucleotides with affinity and specificity for a target, for glycan targets. The approach is capable of rapidly (<1 day) isolating high affinity (uM KD) aptamers with limited sample consumption (<500 µg of glycan) on a single microfluidic platform without the need for offline processes. The presented approach has potential to generate easily accessible sensors for the emerging glycomics field.

Session M2B - Chemical Sensors

11:00 - 11:15

M2B.001 MICROFABRICATED SOLUTION CHAMBER FOR HIGH RESOLUTION DIFFRACTED X-RAY TRACKING METHOD TO OBSERVE ION-CHANNEL GATING MOTION

Ikkei Yamauchi[1], Tomoki Tabuchi[1], Yoshikazu Hirai[1], Masayuki Iwamoto[2], Toshiyuki Tsuchiya[1], Hirofumi Shimizu[2], and Osamu Tabata[1]
[1]Kyoto University, JAPAN and [2]University of Fukui, JAPAN

We report a novel solution chamber for high resolutions diffracted X-ray tracking method that enables to capture motions of ion-channel proteins upon gating. In this chamber, an observation window consists of silicon nitride membrane to reduce a background noise due to X-ray scattering. The suitable chamber height for both sufficient chamber volume and low background noise was clarified. Motions of ion channel were clearly captured with our chamber, and gating dynamics was successfully analyzed.

11:15 - 11:30

M2B.002 INTEGRATED MULTI-VAPOR MICRO COLLECTOR-INJECTOR (µCOIN) FOR µGC

Changhua Zhan[1], Muhammad Akbar[1], Robert Hower[1], Junqi Wang[1], Nicolas Nunovero[1], Joseph Potkay[1,2], and Edward Zellers[1]
[1]University of Michigan, USA and [2]Veterans Administration Ann Arbor Healthcare System, USA

We present a microscale collector-injector (µCOIN) for integration into field-deployable gas chromatographic microsystems (µGC) for analyzing volatile organic compounds. µCOIN consists of a micro passive preconcentrator (µPP) and a micro progressively heated injector (µPHI). We achieved zero-power (diffusional) µPP sampling rates that remain nearly constant for up to 24 hr (fixed, low conc.). The µPHI can provide injection bands < 250 ms wide at ≤ 3 mL/min for most analytes.

11:30 - 11:45

M2B.003 TARGET RECYCLING SIGNAL AMPLIFICATION BASED MICROARRAY PLATFORM FOR HIGH-EFFICIENCY MERCURY AND LEAD IONS DETECTION

Shixing Chen[1], Yi Yang[1], Zonglin Huang[1], Hui Wang[1], Xuanlin Yang[2], Yuelin Wang[1], Shiping Song[1] and Tie Li[1]
[1]Chinese Academy of Sciences (CAS), CHINA and [2]Institute of NBC Defense, PLA Army, CHINA

For trace analysis of heavy metals, a Y type DNA structure based signal amplification system and microarray platform is announced to detect lead and mercury. The results show LOD of 0.5 pM and 0.6 pM for Hg2+ and Pb2+; high discriminating ability from interfering ions such as Mn2+, Cu2+ and Ca2+; the optimal incubation time was only 0.5 hour. Compared to the enzyme method, the novel system holds great application ability with robust, ultra-high sensitivity, high selectivity and high-throughput.

11:45 - 12:00

M2B.004 IN-PLANTA NITRATE DETECTION USING INSERTABLE PLANT MICROSENSOR

Yueyi Jiao[1], Xinran Wang[1], Yuncong Chen[1], Michael J. Castellano[1], James C. Schnable[2], Patrick S. Schnable[1], and Liang Dong[1]
[1]Iowa State University, USA and [2]University of Nebraska-Lincoln, USA

We develop a sensor that measures plant nitrate levels over time.

12:00 - 12:15

M2B.005 REAL-TIME EVALUATION OF SCATTERING STRENGTH ON GRAPHENE FET FOR SELECTIVE SENSING OF CHEMICAL VAPORS

Huiliang Liu[1], Yumeng Liu[2], Yao Chu[1], Takeshi Hayasaka[2], Ying Dong[1], Xiaohao Wang[1], Zheng You[1], and Liwei Lin[1,2]

[1]Tsinghua University, CHINA and [2]University of California, Berkeley, USA

We develop a real-time evaluation method to characterize the scattering strength of chemical vapors on graphene transistors at room temperature. The quantitative test results for three chemical vapors (water, methanol, and ethanol) are presented. The selectivity is illustrated with differentiable characteristics of scattering strength in the binary mixture scenarios. As such, the proposed method of real-time scattering strength evaluation can offer a potential solution for selective gas sensing.

12:15 - 12:30

M2B.006 FILM BULK ACOUSTIC WAVE RESONATOR FOR TRACE CHEMICAL WARFARE AGENTS SIMULANTS DETECTION IN MICRO CHROMATOGRAPHY

Jizhou Hu[1], Hemi Qu[1,2], Wenlan Guo[1], Ye Chang[1], Wei Pang[1], and Xuexin Duan[1]

[1]Tianjin University, CHINA and [2]Nankai University, CHINA

We develop the polymer coated film bulk acoustic resonators (FBAR) as a sensitive detector in micro chromatography for the detection of trace chemical warfare agents (CWA) simulants. The FBAR sensor is enclosed in a microfluidic channel and then couples with a microfabricated separation column. The subsequent chromatographic analysis successfully demonstrates the detection of parts per billion (ppb) concentrations of chemical warfare agents (CWAs) simulants in a five components gas mixture.

Session M2C - Acoustic Devices

11:00 - 11:15

M2C.001 DROPLET DELIVERY CONTROL FOR SURFACE ACOUSTIC WAVE NEBULIZATION MASS SPECTROMETRY

Di Sun[1], Karl F. Böhringer[1], Matthew Sorensen[2], Erik Nilsson[2], and David R. Goodlett[3]

[1]University of Washington, USA, [2]Deurion LLC, USA, and [3]University of Maryland, USA

We present a novel atomizer using standingwave type surface acoustic wave nebulization(SAWN). We integrate droplet delivery controlfunctionality with anisotropic ratchet conveyors(ARC) on top of the SAWN surface, which createmicro-size hydrophilic patterns on thehydrophobic coatings. By adopting parylene-C asa stencil mask, the hydrophobicity of the Cytopdoes not degrade during fabrication. Dropletmovement, merging, mixing and nebulizingfunctions are performed with the same electrodearrays.

11:15 - 11:30

M2C.002 REPROGRAMMABLE MICROELECTROMECHANICAL MEMBRANE RESONATOR FOR LOGIC COMPUTATION

Xinxin Liu, Dengfei Yang, Dongyang Chen, Xuying Chen, Xianhao Le, and Jin Xie

Zhejiang University, CHINA

We present a novel piezoelectric microelectromechanical membrane resonator to perform reprogrammable fundamental 2-bit OR, XOR, XNOR and NOT Boolean mechanical computation with either motional output or electrical output. The development of this electromechanical membrane-based resonator paves the way towards highly functional resonant switches and responsive ultrasonic communication.

11:30 - 11:45

M2C.003 CMOS CONTROLLED GHZ ULTRASONIC IMPEDANCE IMAGER

Mamdouh Abdelmejeed, Justin Kuo, Adarsh Ravi, and Amit Lal

Cornell University, USA

We demonstrate a CMOS driven 1-2 GHz ultrasonic pulse/echo imager that can be monolithically integrated in a single-chip and operate at 1.5V battery voltages at 6.8 mW. This work shows a pathway towards single chip ultrasonic impedance imager. A single pixel transducer is scanned in two dimensions to image fingerprints and leaves with 254 dpi resolution. Frame rate is estimated to be 500 fps at 13.6 μJ/frame. The contrast between rubber and air is 3.3:1 for dry rubber and 1.5:1 for wet rubber.

11:45 - 12:00

M2C.004 LARGE ACOUSTOELECTRIC EFFECT IN WAFER BONDED INDIUM GALLIUM ARSENIDE / LITHIUM NIOBATE HETEROSTRUCTURE AUGMENTED BY NOVEL GATE CONTROL

Aleem M. Siddiqui, Lisa P. Hackett, Daniel Dominguez, Anna Tauke-Pedretti, Tom Friedmann, Gregory Peake, Michael R. Miller, James K. Douglas, and Matt Eichenfield

Sandia National Laboratories, USA

We demonstrate a monolithic surfaceacoustic wave amplifier fabricated by state-of-the-art heterogenous integration of a III-VInGaAs-based epitaxial material stack andLiNbO3. Due to superior properties of thematerials employed, there is a large increasein electronic gain compared to previousdemonstrations with reduced powerconsumption. This platform enables furtheradvances in active and non-reciprocalpiezoelectric acoustic devices.

12:00 - 12:15

M2C.005 ACOUSTIC BUBBLE INDUCED MICROSTREAMING FOR THE ENHANCEMENT OF DROPLET MIXING IN ELECTROWETTING (EW) MICROFLUIDIC PLATFORMS

Taegyu Won, Kang Yong Lee, and Sang Kug Chung
Myongji University, KOREA

We develop a new type of electrowetting (EW) driven droplet microfluidic platform enhanced by acoustic bubbles. For the fast and controllable droplet mixing operation, the function of an acoustic bubble induced microstreaming is added to the existing EW microfluidic platform. The EW driven droplet mixing is possible only for hydrophobic surfaces; however, the new function makes it possible even for hydrophilic surfaces. This platform shows highly reliable manipulation of biochemical droplets.

12:15 - 12:30

M2C.006 MICRO-PHOTOACOUSTIC CELL WITH INTEGRATED MICROPHONE FOR SUB-PPM GAS SENSING

Hélène Lhermet, Thierry Verdot, Alexandre Teulle, Audrey Berthelot, Alain Glière, Brigitte Desloges, Frédéric Souchon, Maryse Fournier, Jean-Marc Fédéli, and Jean-Guillaume Coutard
University of Grenoble, Alpes, CEA LETI, FRANCE

This paper demonstrates, for the first time, an on-chip integration of a photoacoustic (PA) detector, one of the main building blocks required for chemical sensing. This MEMS PA detector consists of a miniaturized PA cell within an acoustic transducer based on an innovative microphone architecture. Coupled with a quantum cascade laser (QCL) source, this trace gas detector can measure very low concentrations of less than one part per million.

Session M2D - Soft Robots & Actuators

11:00 - 11:15

M2D.001 OUT-OF-PLANE LONG-RANGE OPERATED SOFT ENGINE WITH DRIVING STRETCHABLE ZONE PLATE AND LED ABILITIES FOR TUNABLE FOCUSED THERAPEUTIC ULTRASONIC AND INFRARED HEATING APPLICATIONS

Guo-Hua Feng and Hong-Yu Liu
National Chung Cheng University, TAIWAN

We develop an innovative soft engine which performs the long-range up-and-down motion with electroactive polymer actuators. It can convert the bending motion of actuators to linear motion by micro-buckles and serpentine structure. The device can further dynamically tune the focus of ultrasonic beam by driving the foil-made Fresnel zone plate. We successfully demonstrate the soft engine stretches the zone plate to tune its focal distance and functionally operates the light-emitting diode.

11:15 - 11:30

M2D.002 LARGE-DISPLACEMENT MICRO PNEUMATIC ACTUATORS BASED ON CORRUGATED PARYLENE FILM

Fade Hu, Luo Chuan, Yuchen Xu, and Zheng You
Tsinghua University, CHINA

We present a flexible Parylene-based micro pneumatic actuator, which features large displacements over 400um. The actuator demonstrates good designability, controllable deformation, and favorable micro-fabrication process compatibility. Furthermore, a novel releasing method is introduced, requiring no sacrificial layer. The finite-element-model simulation of actuators performance tallies well with the experiment.

11:30 - 11:45

M2D.003 UNTETHERED SOFT ROBOTS WITH BIOINSPIRED BONE-AND-FLESH CONSTRUCTS FOR FAST DETERMINISTIC ACTUATION

Renxiao Xu[1], Fanping Sui[1], Gaurav Jalan[1], Pinghsun Lee[1], Liangjie Ren[1], Mohan Sanghadasa[2], and Liwei Lin[1]
[1]University of California, Berkeley, USA and [2]US Army, USA

We present a new class of soft robots inspired by the bone-and-flesh construct in human body. These untethered robots with external magnetic power boast high normalized power density, and ultrafast, deterministic shape actuation. Robots with different elastomer ("flesh") structures and magnet ("bone") placements can complete various tasks quickly and precisely. Our design and operation principle can be potentially extended to even more complex applications.

11:45 - 12:00

M2D.004 BIOMIMETIC MICRO-GEL ROBOT HAVING A SOFT-RIGID HYBRID STRUCTURE

Tomoki Watanabe[1], Yoshiyuki Yokoyama[2], and Takeshi Hayakawa[1]
[1]Chuo University, JAPAN and [2]Toyama Industrial Technology Center, JAPAN

We propose micro-gel robots having a soft-rigid hybrid structure in this study. The soft parts are made from thermoresponsive gel actuator and it can be actuated by irradiating laser on it. The rigid parts are made of SU-8 that sustains entire body of the micro-gel robot. We succeeded in fabrication of the proposed micro-gel robot by using sacrificial layer process. Furthermore, we performed proof of concept of the actuation of the robot with laser irradiation.

12:00 - 12:15

M2D.005 A JUMPING SILICON MICROROBOT WITH ELECTROSTATIC INCHWORM MOTORS AND ENERGY STORING SUBSTRATE SPRINGS

Craig B. Schindler, Joseph T. Greenspun, Hani C. Gomez, and Kristofer S. J. Pister
University of California, Berkeley, USA

We present the first demonstration of a silicon microrobot using electrostatic inchworm motors to store mechanical energy in springs etched into the silicon substrate. The microrobot is fabricated using a two mask silicon on insulator MEMS process with a 40μm device layer and 550μm substrate. The springs in the silicon substrate can store 100μJ of energy, more than 10X greater than what has been demonstrated previously using energy storing springs in the silicon on insulator layer.

12:15 - 12:30

M2D.006 MEMS-PROCESSED ARTIFICIAL MUSCLES WITH FREELY-PROGRAMMABLE ACTUATION DIRECTION

Yannick Folwill, Sanket B. Shah, and Hans Zappe
University of Freiburg, GERMANY

We present a fabrication process which allows the patterning; internal alignment; and integration of liquid crystal elastomer (LCE) actuators for MEMS technology. The actuation direction of LCEs is defined by the internal alignment of the liquid crystal domains; our approach allows definition of arbitrary alignment directions using a wafer-level process. This technology thus allows programming and structuring of artificial muscle actuators with arbitrary actuation direction for MEMS components.

Session M2E - Lithography & 3D Printing

11:00 - 11:15

M2E.001 SUBMICROMETER-SCALE ALL-SOFT ELECTRONICS BASED ON LIQUID METAL

Min-gu Kim, Devin K. Brown, and Oliver Brand
Georgia Institute of Technology, USA

This paper presents a novel fabrication technique to create submicron-scale eutectic gallium-indium alloy (EGaIn) patterns for all-soft electronics. The proposed hybrid lithography process combines electron-beam lithography with soft lithography and enables high resolution and high density all-soft electronic components and microelectrode arrays. Thanks to the intrinsic softness of EGaIn, the fabricated devices can endure mechanical strain >30%, while maintaining electrical functionality.

11:15 - 11:30

M2E.002 UV-LED LITHOGRAPHY FOR MILLIMETER-TALL HIGH-ASPECT RATIO 3D STRUCTURES

Jungkwun "JK" Kim
Kansas State University, USA

This paper presents a multidirectional high-intensity UV-LED lithography scheme for millimeter tall and high-aspect-ratio 3D structures. The proposed UV-LED lithography scheme adopted high-intensity LED array in a range of 0-225 mW/cm2, and the sample holder was programmable to control the tilt-rotational angles. This approach enables the fabrication of new millimeter tall 3D microstructures that have conventionally been impossible to implement.

11:30 - 11:45

M2E.003 PROTEIN LITHOGRAPHY BEYOND THE DIFFRACTION LIMIT USING TERAHERTZ METAMATERIALS

Zhitao Zhou[1], Zijing Wang[2], Chi Gu[1,3], Yanghong Zhang[1] and Tiger H. Tao[1]
[1]Chinese Academy of Sciences (CAS), CHINA, [2]Shanghai Normal University, CHINA and [3]Sun Yat-Sen University, CHINA

Here we report nanolithography of silk proteins using ultrafast THz pulse with a center wavelength of ~300 μm. This is achieved by metamaterial enhanced local high-field THz field. The THz electric field inside the capacitive gaps of the gold split ring resonator (SRR) is enhanced by more than two orders of magnitude. By adjusting the strength of the incident THz pulse, we can precisely control the secondary structure of the silk fibroin in the gap of SRRs.

11:45 - 12:00

M2E.004 A PROCESS TO REALIZE DIRECT LASER WRITTEN ELECTROSTATIC ACTUATOR ELEMENTS IN A CLOSED MICROCAVITY

Sina Reede[1,2], Frank Bunge[1,2], Martin Oellers[1,2], and Michael J. Vellekoop[1,2]
[1]Universität Bremen, GERMANY and [2]Microsystems Center Bremen, GERMANY

An electrostatic actuator made by 2-photon polymerization and integrated in a microcavity is presented. The cavity is closed by wafer-to-wafer bonding of Parylene-C coated silicon and glass wafers. The actuator consists of a free-standing, electrically connected, movable platform with an outer diameter of 260 μm which can act as a microfluidic valve and is supported by conical springs. The process includes the patterning of a metallization on the glass wafer containing 76 μm high structures.

12:00 - 12:15

M2E.005 3D ELECTRON PRINTING IN RECOMBINANT SPIDER SILK PROTEINS AT THE MOLECULAR LEVEL

Nan Qin[1], Zhiheng Gao[2], Yu Zhou[1], and Tiger H. Tao[1,2]
[1]Chinese Academy of Sciences (CAS), CHINA and [2]ShanghaiTech University, CHINA

We report the 3d electron printing of shape-shifting nanodevices at the molecular level, for the first time, using genetically engineered spider silk proteins as the smart materials. This facile and biofriendly nanofabrication method brings us the ability to directly and precisely produce high performance 3d functional nanodevices, for new opportunities in nanorobotics, biomimetics and cell scaffolds.

12:15 - 12:30

M2E.006 3D PRINTING ON MEMS: INTEGRATION OF 3D SHOCK STOPPER ON A MICRO MIRROR

Sebastien Lani, Olivier Chandran, Maxime Auchlin, Ivan Marozau, and Barthelemy Dunan
Centre Suisse d'Electronique et de Microtechnique (CSEM), SWITZERLAND

We have developed a polymer-based 3D shock stopper and absorber based on microsterelithography technology that is integrated onto a prefabricated wafer of a MEMS Micromirror, improving its shock resistance by a factor 4. This development, relying on a modified stereolithography system and equipped with an alignment system, is allowing the integration of complex shape directly onto microsystem at chip or wafer level and is cost effective.

12:30 - 14:30 **Lunch on Own**

13:30 - 14:30 **Industrial Stage Session 1 (Exhibit Hall)**

- 1a Heidelberg Instruments & SwissLitho, GERMANY
- 1b scia Systems GmbH, GERMANY
- 1c i-ROM GmbH, GERMANY
- 1d Innovative Sensor Technology IST AG, SWITZERLAND

14:30 - 16:30 **Poster Session M3P and Exhibit Inspection (refreshments will be served)**
Poster presentations are listed by topic category with their assigned number starting on page 42.

16:30 **Adjourn for the Day**

18:30 - 22:00 **Monday Evening at the Orangerie, Charlottenburg Palace**

Tuesday, 25 June

08:00 **Continental Breakfast in Exhibit Hall**

08:30 - 09:15 **Plenary Presentation II**

T1A.P02 LEARNING CAUSAL MECHANISMS

Bernhard Schölkopf
Max Planck Institute for Intelligent Systems, GERMANY

In machine learning, we use data to automatically find dependences in the world, with the goal of predicting future observations. Most machine learning methods build on statistics, but one can also try to go beyond this, assaying causal structures underlying statistical dependences. Can such causal knowledge help prediction in machine learning tasks? We argue that this is indeed the case, due to the fact that causal models are more robust to changes that occur in real world datasets. We discuss implications of causal models for machine learning tasks, focusing on an assumption of 'independent mechanisms', and discuss an application in the field of exoplanet discovery.

09:15 - 09:30 **Transducers 2021 Announcement**

09:30 - 09:45 **Transition**

Session T1A - Lab on a Disc

09:45 - 10:00

T1A.001 NON-CENTRIFUGAL MICROFLUIDIC NUCLEIC ACID TESTING ON LAB-ON-A-DISC

Gihoon Choi[1] and Weihua Guan
Pennsylvania State University, USA

A novel energy efficient non-centrifugal lab-on-a-disc nucleic acid testing device without requiring liquid motion. Streamlined DNA extraction, amplification, and real-time detection on a single microfluidic reagent disc are achieved by actuating the DNA-carrying magnetic beads against stationary reagent droplets. Using malaria model, we demonstrated detection limit of 0.5 parasites/µl, sufficient for detecting asymptomatic malaria parasite carriers.

10:00 - 10:15

T1A.002 LABSLICE XL – A CENTRIFUGAL MICROFLUIDIC CARTRIDGE FOR THE AUTOMATED BIO-CHEMICAL PROCESSING OF INDUSTRIAL PROCESS WATER

Stefan Burger[1], Lisa Drechsel[1], Ana R. Homann[1], Felix von Stetten[1], Roland Zengerle[1,2], and Nils Paust[1]
[1]Hahn-Schickard, GERMANY and [2]University of Freiburg, GERMANY

The LabSlice XL is a novel centrifugal microfluidic platform for the extraction of nucleic acids from complex sample matrices such as process water. A standard filter membrane is used to collect pathogens from large volumes and is directly inserted into a microfluidic cartridge. A standard laboratory centrifuge automates the bio-chemical procedure of lysate purification, DNA extraction, and PCR preparation. A convenient user interface and complete reagent pre-storage ensure user friendliness.

10:15 - 10:30

T1A.003 3D PRINTED BIO-SENSING CHIP FOR THE DETERMINATION OF BACTERIA ANTIBIOTIC-RESISTANT PROFILE

Po-Chen Yeh[1,2], Juhong Chen[1], Ilbey Karakurt[1], and Liwei Lin[1]
[1]University of California, Berkeley, USA and [2]National Chiao Tung University, TAIWAN

We present a novel 3D printed bio-sensing chip to characterize the profile of the bacteria antibiotic-resistant reactions in real time. To achieve the disposable device for real-time antibiotic-resistant profiling, the 3D printing is adopt to fabricate the chip, a waterproof treatment is applied to the fabricated chips, and a smart phone camera with the RGB pixel analysis app is used for the color identification.

10:30 - 10:45

T1A.004 MINIMIZING ETHANOL CARRY-OVER IN CENTRIFUGAL MICROFLUIDIC NUCLEIC ACID EXTRACTION BY ADVANCED BEAD HANDLING AND MANAGEMENT OF DIFFUSIVE MASS TRANSFER

Sebastian Hin[1], Nils Paust[1,2], Markus Rombach[1], Jan Lüddecke[1], Mara Specht[1], Roland Zengerle[1,2], and Konstantinos Mitsakakis[1,2]
[1]Hahn-Schickard, GERMANY and [2]University of Freiburg, GERMANY

We present three concepts for centrifugal microfluidics addressing the frequently reported challenge of ethanol carry-over in bead-based nucleic acid (NA) extraction. We identified capillary co-transport of ethanol in bead clusters and vapor diffusion as carry-over sources. Capillary co-transport was reduced by bead manipulation at continuous rotation. Diffusion was counteracted by cross-section reduction at the diffusion path or introduction of a dynamic pressure-driven counter-flow of air.

Session T1B - E&M Field Sensors I

09:45 - 10:00

T1B.001 A CMOS HALL-BASED MAGNETIC MULTISENSOR SYSTEM FREE FROM PARASITIC EFFECTS OF TEMPERATURE AND PACKAGE STRESS

Samuel Huber[1], Zsombor Lazar[1], Moritz Berger[2], and Oliver Paul[2]
[1]Melexis, SWITZERLAND and [2]University of Freiburg, GERMANY

We designed, implemented, and validated a novel approach for cross-sensitivity compensation in a fully integrated CMOS Hall magnetic multisensor system. While exposing packaged devices to temperature cycles between -40°C and 125°C, humidity changes, and external forces up to 30 N we combined signals from Hall, stress, and temperature sensors in a single compensation step in the digital domain. We achieved to eliminate all parasitics and to stabilize the magnetic sensitivity to 1±0.004.

10:00 - 10:15

T1B.002 AN ELECTROMAGNETIC INDUCTION BASED TORSIONAL MEMS MAGNETOMETER FOR IN-PLANE MAGNETIC FIELD SENSING

Song Liu, Hengmao Liang, and Bin Xiong
Chinese Academy of Sciences (CAS), CHINA

We demonstrate an electromagnetic induction based torsional MEMS magnetometer used to sense in-plane magnetic field. The magnetometer registers a high sensitivity of 100 mV/mT and resolution of 25 μT/√Hz in air. With the industrial vacuum packaging (~1 mBar), the sensitivity can be improved by at least two orders of magnitude and a sub-μT resolution is achieved, making the proposed magnetometer suitable for automotive industry, navigation systems and non-destructive material testing.

10:15 - 10:30

T1B.003 A SILICON MOLDED METAL TRANSFER PROCESS FOR ON-CHIP SUSPENDED POWER INDUCTORS

Yixiao Ding[1], Xiangming Fang[2], Rongxiang Wu[3], Qili Guo[4], and Johnny K.O. Sin[1]
[1]Hong Kong University of Science and Technology, HONG KONG, [2]Shenzhen CoilEasy Technologies Limited, CHINA, [3]University of Electronic Science and Technology of China, CHINA, and [4]Mornsun Guangzhou Science & Technology Co., Ltd., CHINA

We develop a silicon molded metal transfer process to build suspended thick-winding inductors for high-frequency power management applications. Compared with other suspended inductors fabrication techniques, the developed process can increase the suspended inductor winding thickness by more than 3 times. The thicker winding and suspended structure can reduce DC and AC losses, and lead to a higher power efficiency.

10:30 - 10:45

T1B.004 ELEVENTH ORDER LAMB WAVE MODE BICONVEX PIEZOELECTRIC LORENTZ FORCE MAGNETOMETER FOR SCALING UP RESPONSIVITY AND BANDWIDTH

Sagnik Ghosh and Joshua Lee
City University of Hong Kong, HONG KONG

We report a piezoelectric Lorentz force magnetometer (LFM) that exploits the 11th harmonic Lamb wave mode to significantly enhance sensitivity relative to the fundamental mode. Compared to state-of-art capacitive LFMs encapsulated in vacuum for high quality factor (Q), our device herein boasts a ten-fold boost in sensitivity in ambient pressure.

Session T1C - Ultrasonic I

09:45 - 10:00

T1C.001 ZERO-POWER ACOUSTIC WAKE-UP RECEIVER BASED ON DMUT TRANSMITTER, PMUTS ARRAYS RECEIVERS AND MEMS SWITCHES FOR INTRABODY LINKS

Flavius Pop, Bernard Herrera, William Zhu, Meruyert Assylbekova, Cristian Cassella, Nicole McGruer, and Matteo Rinaldi
Northeastern University, USA

This paper demonstrates, for the first time, a zero-power acoustic wake-up receiver for intrabody links, allowing implanted medical devices (IMD) to minimize the IDLE power consumption. This architecture is based on Directly Modulated Ultrasonic Transducer (dMUT), Piezoelectric Micromachined Ultrasonic Transducer (pMUT) and Micro Electro-Mechanical System (MEMS) switch. The dMUT and pMUT establish and acoustic link sensitive to very low signals, which will trigger the switch and turn on the IMD.

10:00 - 10:15

T1C.002 A HIGH-ACCURACY IN-AIR REFLECTIVE RANGEFINDER VIA PMUTS ARRAYS USING MULTI-FREQUENCY CONTINUOUS WAVES

Xuying Chen[1], Jinghui Xu[2,3], Hong Ding[1], Xinxin Liu[1], Dongyang Chen[1], and Jin Xie[1]
[1]Zhejiang University, CHINA, [2]MEMSound Pte Ltd, SINGAPORE, and [3]Guangzhou Chen Fang Info Tech Ltd., CHINA

This paper reports a high-accuracy in-air reflective rangefinder based on piezoelectric micromachined ultrasound transducers (pMUTs) array using multi-frequency continuous waves (MFCW). The 3σ accuracy, first-order resolution and second-order resolution of the short distance measurement (<100mm) is 0.0711 mm, 0.096 mm/° and 1.934 μm/° respectively, which is 1.8208 mm, 0.481 mm/° and 1.954 μm/° for long distance measurement (100mm-300mm).

10:15 - 10:30

T1C.003 DISPLAY COMPATIBLE PMUT ARRAY FOR MID-AIR HAPTIC FEEDBACK

Alexandre Halbach, Pieter Gijsenbergh, Yongbin Jeong, Wouter Devriese, Hang Gao, Margo Billen, Guilherme B. Torri, Christoper Chare, David Cheyns, Xavier Rottenberg, and Veronique Rochus
IMEC, BELGIUM

We present a micromachined piezoelectric ultrasonic transducer (PMUT) array that has the potential to provide a mid-air haptic feedback user experience. Compared to existing technologies based on bulk transducers, this array is fabricated on a polymer-based, display compatible, large area technology with the potential to be flexible and transparent. It is thus a good candidate for direct integration on top of large displays and allows to fabricate dense PMUT arrays for a fine haptic experience.

10:30 - 10:45

T1C.004 HIGHLY EFFICIENT PIEZOELECTRIC MICROMACHINED ULTRASOUND TRANSDUCER (PMUT) FOR UNDERWATER SENSOR NETWORKS

Sina Sadeghpour, Michael Kraft, and Robert Puers
University of Leuven (KU Leuven), BELGIUM

We developed a low voltage (<3V) ultrasound transducer based on a PMUT array to perform underwater communication at distances of 1-2 m. The purposed transducer generates an ultrasound wave by the vibration of a bulk Si substrate, bonded to a PCB and actuated by the actuation of several PMUT elements. Basically, the reactive power generated by the PMUTs produces vibration in the nearby water, resulting in the vibration of the entire substrate. This leads to a 208.9Pa/V@1cm transmission response.

Session T1D - Nanosensors

09:45 - 10:00

T1D.001 MANIPULATION OF BIOMOLECULES INTO NANOGAP BY PLASMONIC OPTICAL EXCITATION FOR HIGHLY SENSITIVE BIOSENSING

Akihiro Morita, Akio Uesugi, Koji Sugano, and Yoshitada Isono
Kobe University, JAPAN

This paper demonstrated the manipulation of DNA oligomers with 16 adenine molecules using a plasmonic nanogap. The optical excitation caused plasmonic dielectrophoresis or/and thermophoresis of molecules to the nanogap due to huge gradient of an electric field. We confirmed by a single-molecule electrical measurement that the DNA oligomers were transported to the nanogap, resulting in highly sensitive biosensing based on an electrical or optical measurement.

10:00 - 10:15

T1D.002 NOVEL ALL-SOLID-STATE SOIL NUTRIENT SENSOR USING NANOCOMPOSITE OF POLY(3-OCTYL-THIOPHENE) AND MOLYBDENUM SULFATE

Md. Azahar Ali[1], Xinran Wang[1], Yuncong Chen[1], Yueyi Jiao[1], Michael J. Castellano[1], James C. Schnable[2], Patrick S. Schnable[1], and Liang Dong[1]
[1]Iowa State University, USA and [2]University of Nebraska, USA

We develop a sensor that measures soil nitrate levels over time.

10:15 - 10:30

T1D.003 DIELECTROPHORETIC-ASSISTED BIOSENSOR FOR SINGLE-CELL CHARACTERIZATION AT MMWAVE FREQUENCIES IN CMOS 28NM TECHNOLOGY

Ali Ameri[1], Luya Zhang[1], Asmaysinh Gharia[1], Mekhail Anwar[2], and Ali M. Niknejad[1]
[1]University of California, Berkeley, USA and [2]University of California, San Francisco, USA

In this work, we present a Dielectrophoretic (DEP) assisted mmWave permittivity sensor for single cell detection and characterization on a CMOS chip. A novel microfluidic package is built for delivering the cells to the chip. Positive DEP is used to capture the samples in the channel and align them with the mmWave sensor to achieve maximum sensitivity. The DEP generation circuits and mmWave sensor are co-designed and integrated on the same chip in a CMOS 28nm technology.

10:30 - 10:45

T1D.004 ANALYSIS OF POLYCYCLIC AROMATIC HYDROCARBONS (PAH) USING GAS CHROMATOGRAPHY AND NEMS DETECTOR

Olivier Legendre, Carine Ladner, Eric Ollier, Thomas Alava, Florence Ricoul, Séverine Vignoud, and Bruno Fain
University of Grenoble, Alpes, CEA-LETI, FRANCE

We describe the analysis of amixture of 16 polycyclic aromatic hydrocarbons(PAH) using gas chromatography (GC) andnano-electromechanical systems (NEMS). Theperformance of NEMS to detect PAHs is assessedand compared with that of commercial flameionization detector (FID). The limit of detectionof the GC-NEMS system ranges from 70 pg to500 pg, which confirms the potential of NEMS toquantify high molecular weight molecules. Thelimitations of such a system to detect PAHs arediscussed.

Session T1E - Fabrication Technologies I

09:45 - 10:00

T1E.001 FABRICATION OF CAVITY-SEALED OPTICAL INTERFEROMETRIC SURFACE STRESS BIOSENSOR BY THIN FILM TRANSFER TECHNIQUE

Toshiaki Takahashi[1], Yong-Joon Choi[1], Satoshi Maruyama[1], Taki Miki[1], Kazuaki Sawada[1], and Kazuhiro Takahashi[1,2]

[1]Toyohahsi University of Technology, JAPAN and [2]JST, PRESTO, JAPAN

We developed a surface stress sensor based on a MEMS interferometer with cavity-sealed structure by transfer technique for highly sensitive biosensing. The proposed MEMS interferometer can measure the membrane deflection caused by target molecule adsorption as the spectral shift. We successfully obtained the spectral shift of 77 nm in 10 minutes associated with the antigen-antibody reaction with a concentration of 1 ng/ml, which improved by 16.7 fold compared with the conventional sensor.

10:00 - 10:15

T1E.002 DESIGN AND MANUFACTURE OF A SILICON PENDULUM FOR PTB'S NANOFORCE STANDARD FACILITY

Sebastian Buetefisch[1], Thomas Weimann[1], Vladimir Nesterov[1], Anke Vierheller[2], and Andreas Dietzel[2]

[1]Physikalisch-Technische Bundesanstalt, GERMANY and [2]Technical University Braunschweig, GERMANY

This article presents the design and micro manufacture of a novel silicon pendulum to be used at the German National Metrology Lab (PTB) for the measurement of ultra-small forces. The nanoforce standard facility with the previous pendulum manufactured by precision engineering methods together with the constructive requirements are described. Two design variants are discussed. The structures were realized in monocrystalline silicone using wet chemical anisotropic etching methods.

10:15 - 10:30

T1E.003 HIGHLY RELIABLE PIEZOELECTRIC PROCESS TECHNOLOGY IN VOLUME FOUNDRY FOR EMERGING MEMS APPLICATIONS

Victor Shih, Sean Cheng, You-Ru Lin, Anderson Lin, Yan-Jie Liao, Ching-Hui Lin, Fu-Chun Huang, Kelvin Tai, Fan Hu, Yi-Heng Tsai, Yen-Wen Chen, Kai-Fung Chang, Leo Tsai, Ching-Hua Chiu, Leo Tsai, Vincent Teng, Chih-Ming Chen, Terrence Yu, Yeur-Luen Tu, Lee-Chuan Tseng, Julian Lee, Benior Chen, Shih-Fen Huang, and Alexander Kalnitsky

Taiwan Semiconductor Manufacturing Company (TSMC), TAIWAN

This work presents the piezoelectric process technology developed in a high volume foundry for emerging MEMS applications. Innovative reliability enhancement techniques for piezoelectric devices are demonstrated to significantly boost:(1)breakdown voltage from 30V to 110V,(2)time-dependent-dielectric-breakdown lifetime by 100X,(3)temperature-humidity-bias robustness(0% failure),(4)imprint and fatigue control(99% recovery) to fulfill reliability criteria of emerging MEMS applications.

10:30 - 10:45

T1E.004 FABRICATION OF QUARTZ NANOCONE FORESTS FOR TRANSPARENT SURFACE-ENHANCED RAMAN SCATTERING DEVICES

Qian Zhao[1,2], Yudong Yang[1], Bo Gui[1,2], Haiyang Mao[1], Ruirui Li[1], and Weibing Wang[1]

[1]Chinese Academy of Sciences (CAS), CHINA and [2]University of Chinese Academy of Sciences, CHINA

A transparent surface-enhanced Raman scattering(SERS) substrate integrated with quartz nanocone forests is obtained through a two-step reactive-ion-etching and a metal-nanoparticle deposition step. With such a substrate, Raman laser can be incident from back-side of quartz thus is able to avoid influences from cap layers, fluids and analyte molecules on laser propagation and signal collections. This indicates a way to broaden detection ranges for microfluidic SERS devices.

10:45 - 11:15 **Break and Exhibit Inspection**

Session T2A - Microfluidics I

11:15 - 11:30

T2A.001 LIQUID PUMPING AND MIXING BY PZT SYNTHETIC JET

Luan L. Van[1], Cuong N. Nguyen[1], Tuan T. Nguyen[2], Thien X. Dinh[3], Canh-Dung Tran[4], Lam Dang Bao[2], Tung Thanh Bui[1], Van Thanh Dau[5], and Trinh Chu Duc[1]

[1]Vietnam National University, VIETNAM, [2]Hanoi University of Science and Technology, VIETNAM, [3]Ritsumeikan University, JAPAN, [4]University of Southern Queensland, AUSTRALIA, and [5]Griffith University, AUSTRALIA

A suitable compact and low-cost device for liquid delivery, mixing and monitoring is developed. The device can pump various fluids at high flowrate while mixing them efficiently using a synthetic jet actuated by a single piezoelectric membrane. Mixing is monitored by built-in capacitance sensors integrated downstream the mixing zone. The device featuring completeness, cost-effectiveness neglects various process in a current bio-related microfluidic system.

11:30 - 11:45

T2A.002 DECODING OF CODE-MULTIPLEXED COULTER SENSOR SIGNALS VIA DEEP LEARNING

Ningquan Wang, Ruxiu Liu, Norh Asmare, Dakshitha B. Anandakumar, and A. Fatih Sarioglu
Georgia Institute of Technology, USA

We introduce a deep learning-based algorithm to process signals from a code-multiplexed Coulter sensor network integrated in a microfluidic device. The algorithm is able to extract the spatial information of suspended particles detected by the sensor network. At the same time, our algorithm yields a high decoding accuracy (>87%) and a fast signal processing rate (>800 particles/s), paving the way for real-time particle analysis using integrated code-multiplexed Coulter sensor networks.

11:45 - 12:00

T2A.003 MICROFLUDIC FABRICATION OF LIQUID-MEDIATED MATERIALS INTO MULTIPLE HETEROGENEOUS AND NETWORKED NANOSTRUCTURES

Juyeol Bae, Jun Gyu Park, and Taesung Kim
Ulsan National Institute of Science and Technology (UNIST), KOREA

We report a novel microfluidic technique to pattern liquid into 2D foam structures. Using the thinning liquid space as nanoscale molds for bottom-up assembly of liquid-mediated materials, we achieved multi-integrated patterns of various heterogeneous materials that are structured to 2D or 3D networked micro- and nanowire on a flexible substrate, in a simple, low-cost, scalable, and direct-writing manner.

12:00 - 12:15

T2A.004 PICOLITER DROPLET GENERATION FOR FAST MONITORING THE BRAIN CHEMISTRY WITH SCALED SILICON NANODYALISIS PROBE

Yan Zhang, Ari Esters, Oscar Bi, and Yurii Vlasov
University of Illinois, Urbana–Champaign, USA

To monitor neurochemicals while minimizing brain damage, a dialysis system is developed with fluidic channels scaled to 5μm-radius to fit into 15x50μm2 silicon neural probe. To improve time resolution, analyte is segmented into droplets that, however, become unstable at resulting slow flow rate of ~nL/min. We found T-junction angle modulates segmentation regimes by interplay between differential pressure and shear force, and further demonstrated stable droplet generation by optimized geometry.

12:15 - 12:30

T2A.005 Z-AXIS CONTROLLABLE MILLE-FEUILLE ELECTRODE ELECTROROTATION DEVICE UTILIZING LEVITATION EFFECT

Yuki Okamoto[1], Taku Tsuchiya[1], Charles Moslonka[5], Yu-Sheng Lin[2], Sung Tsang[3], Frédéric Marty[4], Ayako Mizushima[1], Chen-li Sun[3], Hsiang-Yu Wang[2], Agnès Tixier-Mita[1], Olivier Français[3], Bruno Le Pioufle[5], and Yoshio Mita[1]
[1]University of Tokyo, JAPAN, [2]National Tsing Hua University, TAIWAN, [3]National Taiwan University, TAIWAN, [4]ESIEE Paris, FRANCE, and [5]École normale supérieure Paris-Saclay, FRANCE

This paper presents a new electrorotation (ROT) device composed of thick walls and multi electrode layers, called as mille-feuille electrode device. The proposed device has three advantages: (1) The height of a measured particle is controllable by adjusting levitation forces. (2) The rotation speed is less affected by the friction to the substrates. (3) The electrode layers are extensible.

12:30 - 12:15

T2A.006 SOFT SPIRAL-SHAPED MICRO-SWIMMER WITH PROPULSION FORCE CONTROL BY PITCH CHANGE

Koki Yoshida and Hiroaki Onoe
Keio University, JAPAN

This paper describes a soft spiral-shaped micro-swimmer with propulsion force controlled by pitch change. We achieved the pitch change of the double-layered micro-swimmer by temperature stimulus and confirmed that the propulsion force of the swimmer was controlled by the pitch change. Finally, we demonstrated that micro-swimmer thrust with deformation in the curve tube.

Session T2B - E&M Field Sensors II

11:15 - 11:45 **Invited Speaker**

T2B.001 QUANTUM SENSORS IN DIAMOND: TECHNOLOGY ROADMAP

Christian Degen[1], Gabriel Puebla-Hellmann[1,2], and Jan Rhensius[1,2]
[1]ETH Zürich, SWITZERLAND and [2]QZabre LLC, SWITZERLAND

Diamond has emerged as a unique material for a variety of applications, both because it is very robust and because it has defects with interesting properties. One of these defects, the nitrogen-vacancy color center (NV center) shows quantum behavior up to above room temperature. We are exploring diamond as a platform for realizing nanoscale sensors with exquisite sensitivities and new capabilities.

11:45 - 12:00

T2B.003 A MICROASSEMBLED TRIANGULAR-PRISM-SHAPE THREE-DIMENSIONAL ELECTRIC FIELD SENSOR

Biyun Ling[1,2], Chunrong Peng[1], Ren Ren[1], Fengjie Zheng[1], Zhaozhi Chu[1], Zhouwei Zhang[1,2], Hucheng Lei[1,2], and Shanhong Xia[1,2]

[1]Chinese Academy of Sciences (CAS), CHINA and [2]University of Chinese Academy of Sciences, CHINA

This paper presents a microassembled 3D electric field sensor (EFS), which is a chip-level compact triangular-prism-shape sensor consisting of X-, Y- and Z-axis EF sensing chips. Interlocking latches are employed to ensure the orthogonality of the three sensing axes. Structures of each sensing chip are symmetrically designed for reducing cross-axis coupling interference. A novel micromachining process is developed to fabricate this 3D EFS. Good performances have been demonstrated by experiments.

12:00 - 12:15

T2B.004 A MODE-LOCALIZED VOLTMETER WITH RESOLUTION OF 46.8 NANOVOLTS

Jiaju Liang, Yongcun Hao, Hao Kang, Bing Ruan and Honglong Chang

Northwestern Polytechnical Univerisity, CHINA

This paper for the first time reports a mode-localized voltmeter. It uses weakly coupled resonators (WCRs) as the sensitive element. Then input voltage causes stiffness perturbation to one resonator and influences the energy distribution of a WCRs system, finally leads to a drastic change of the mode shape. The measurement is not sensitive to temperature change, which is important for reducing temperature drift. And the resolution of the voltmeter is 46.8 nV/√Hz.

12:15 - 12:30

T2B.005 UNCOOLED MEMS INFRARED FOCAL PLANE ARRAY WITH INTEGRATED METAMATERIAL PERFECT ABSORBERS

Xiaoguang Zhao, Chunxu Chen, Aobo Li, Guangwu Duan, Joseph Paller, and Xin Zhang

Boston University, USA

We develop an infrared focal plane array (FPA) enabled by integrating MEMS with metamaterial perfect absorbers (MPAs), which provide highly spectral-selective response. The MPAs, consisting of a metamaterial layer, silicon nitride spacer and ground plane and operating at the mid-infrared wavelength, are integrated with bi-material cantilever thermal detectors. This work provides a novel paradigm to combine artificially engineered materials with MEMS targeting infrared imaging applications.

Session T2C - Ultrasonic II

11:15 - 11:30

T2C.001 FULLY TRANSPARENT PIEZOELECTRIC ULTRASONIC TRANSDUCER WITH 3D PRINTED SUBSTRATE

Sedat Pala and Liwei Lin

University of California, Berkeley, USA

In this paper, a fully transparent piezoelectric ultrasonic transducer with integrated 3D printed substrate is presented. The fabricated ultrasonic transducer working in air medium is fully compatible with display applications. The design, fabrication method and test results are presented. The optical transparency of the device is demonstrated. Results indicate that the fabricated structures have the potential for displays applications such as gesture recognitions, and finger print sensing.

11:30 - 11:45

T2C.002 SPURIOUS MODE FREE HEXAGONAL PMUT ARRAY

Yuri Kusano, Guo-Lun Luo, and David A. Horsley

University of California, Davis, USA

This paper presents a hexagonal piezoelectric micromachined ultrasonic transducer (PMUT) array that can avoid spurious modes known to occur by mode coupling with adjacent elements. By designing an optimal hexagonal PMUT array with 10 um spacing resulting in high fill-factor, we were able to experimentally demonstrate well-matched spurious mode free resonances. Furthermore, the effects of the center PMUT in arrays were investigated through FEM simulations and experimental measurements.

11:45 - 12:15 **Invited Speaker**

T2C.003 MEMS TRANSDUCERS FOR NON-INVASIVE ULTRASOUND BRAIN STIMULATION

Hyungguk Kim, Seongyeon Kim, Sang-Mok Lee, Byung Bum Kang, Yehhyun Jo, Geon Kook, Chaerin Oh, Mi Kyung Kim, Hyojung Kim, and **Hyunjoo J. Lee**

Korea Advanced Institute of Science and Technology (KAIST)

Non-invasive brain stimulation is a promising alternative therapeutic means for brain disorders. Among various modalities, ultrasound offers distinct advantages such as non-invasiveness, focusing capability, and in-depth targeting. This talk will describe the design, implementation, and in vivo results of our miniature MEMS ultrasound transducer, a CMUT ring array, designed for non-invasive neuromodulation for freely-moving small animals. In addition, a short critical review of the potential mechanisms for ultrasound neuromodulation will be presented.

12:15 - 12:30

T2C.005 CHARACTERIZATION OF EPITAXIAL-PZT/SI PIEZOELECTRIC MICROMACHINED ULTRASONIC TRANSDUCER (PMUT) AND ITS PHASED ARRAY SYSTEM

Ziyi Liu[1], Shinya Yoshida[1], Toshiaki Horie[2], Shoji Okamoto[2], Ryouichi Takayama[2], and Shuji Tanaka[1]

[1]Tohoku University, JAPAN and [2]Panasonic Corporation, JAPAN

We developed a piezoelectric micromachined ultrasonic transducer (pMUT) based on an epitaxial PZT thin film. We demonstrated this pMUT promises to provide a higher performance than the pMUT based on the polycrystalline PZT thin film by evaluating their transmission and receipt performances. A beamforming system with the epitaxial-PZT pMUT array was also developed and evaluated. Finally, we successfully demonstrated the image of a polydimethylsiloxane-based phantom.

12:30 - 12:45

T2C.006 FLEXIBLE SOI-BASED PIEZOELECTRIC MICROMACHINED ULTRASOUND TRANSDUCER (PMUT) ARRAYS

Sina Sadeghpour, Bram Lips, Michael Kraft, and Robert Puers
University of Leuven (KU Leuven), BELGIUM

An extremely flexible PMUT array structure was realized, based on Silicon-on-Isolator (SOI) technology. Six rigid islands of PMUT arrays were connected by means of silicon springs, fabricated by Deep Reactive Ion Etching (DRIE). These enable ultra-miniaturization. Each island consists of a 3x3 PMUT array. The PMUTs are 410µm in diameter, with a resonance frequency of 470kHz in air and 160kHz underwater. The flexible arrays were wrapped around a 5x5mm cube to create an omnidirectional transducer.

Session T2D - Nanoscale Devices & Experiments

11:15 - 11:30

T2D.001 FREQUENCY TUNING OF TWO-DIMENSIONAL NANOELECTROMECHANICAL RESONATORS VIA COMB-DRIVE MEMS ACTUATORS

Yong Xie[1,2], Jaesung Lee[1], Hao Jia[1], and Philip X.-L. Feng[1]
[1]Case Western Reserve University, USA and [2]Xidian University, CHINA

This paper presents the design, fabrication, and measurement on frequency tuning of atomically thin graphene and MoS_2 resonators by controlling their built-in tension levels via integrated comb-drive MEMS actuators. Innovative claims include: (1) demonstrating unprecedentedly broad frequency tuning range via comb-drives; (2) elucidating different frequency tuning behaviors via monitoring multimode resonances; (3) manipulating built-in tension up to the crystalline materials' breaking limit.

11:30 - 11:45

T2D.002 AN ULTRABROADBAND INFRARED OPTICAL MODULATOR OF 3D NANOANTENNA FABRICATED BY FOCUSED ION BEAM - STRESS INDUCED DEFORMATION

Xiaoyu Chen, Yifei Mao, Zhuojie Chen, Shengxiao Jin, Wengang Wu, Jun Xu, and Rui Zhu
Peking University, CHINA

We present a novel three-dimensional (3D) nanoantenna array, consisting of double-claw shape unit cell, and the array is employed as an ultrabroadband infrared (IR) optical modulator. A focused ion beam stress-introduced deformation (FIB-SID) technique is used to fabricate the nanoantenna. The measured reflection spectra of the device show a significant modulation, covering from long-wave (9.93 µm) to short-wave (2.04 µm) IR regimes, with tiny change of the distance of double claw.

11:45 - 12:00

T2D.003 MICRO-REACTOR CHIP FOR REAL-TIME OBSERVING METAL-ORGANIC FRAMEWORK (MOF) NANOCRYSTALS GROWN UNDER IN-SITU TRANSMISSION ELECTRON MICROSCOPY

Xueqing Wang, Pengcheng Xu, Haitao Yu, and Xinxin Li
Chinese Academy of Sciences (CAS), CHINA

We report a new method for real-time observing gas-solid reaction to grow MOF crystals under in-situ TEM. A micro-reactor integrated with SiNx windows, gas channel and micro-heater is fabricated. The ligand molecules are encapsulated in zeolite and then sustained released to avoid blocking the tiny gas channel. By this method, dynamic process of vaporized trimesic acid molecules reacting with ZnO nanowire for MOF Zn3(BTC)2 construction is real-time observed.

12:00 - 12:15

T2D.004 ENGINEERING TUNABLE STRAIN FIELDS IN SUSPENDED GRAPHENE BY MICRO ELECTROMECHANICAL SYSTEMS

Jens Sonntag[1,2], Matthias Goldsche[1,2], Tymofiy Khodkov[1], Gerard Verbiest[1], Sven Reichardt[3], Nils von den Driesch[2], Dan Buca[2], and Christoph Stampfer[1,2]
[1]RWTH Aachen University, GERMANY, and [2]Forschungszentrum Jülich, GERMANY, and [3]University of Oxford, UK

We develop a silicon-based micro electromechanical platform for the investigation of the electromechanical coupling in graphene. Key innovations of our technique include: full control over induced strain fields and doping levels within the graphene and their characterization via confocal Raman spectroscopy; and the ability to detect the mechanical coupling of the graphene sheet to the MEMS device with ultra-high sensitivity via their mechanical resonator eigenfrequencies.

12:15 - 12:30

T2D.005 CONCENTRATION MATCH BASED DILUTION FOR CLOGGING-FREE FILTRATION THROUGH MICROPORE ARRAYS

Yaoping Liu[1], Xinyue Deng[1,2], Jingquan Liu[3] and Wei Wang[1,3]
[1]Peking University, CHINA, [2]Peking University Health Science Center, CHINA
[3]Shanghai Jiao Tong University, CHINA

We proposed a concentration match based modulation mechanism and developed a dilution aiding method to solve the clogging problem in micropore array filtration for the first time. Theoretical analysis and experimental verification demonstrated this strategy could simply and reliably fulfill a clogging-free filtration and a high-efficiency separation of different targets from complicated clinical samples. This strategy will be widely applicable in micropore array filtration based liquid biopsy.

12:30 - 12:45

T2D.006 ENRICHMENT OF EXTRACELLULAR VESICLES VIA LIPID NANOPROBE-FUNCTIONALIZED NANOSTRUCTURED SILICA MICRODEVICE

Yuan Wan[1,2], Mackenzie Maurer[2], Hong-Zhang He[2], Yi-Qiu Xia[2], Wen-Long Zhang[2], Si-Jie Hao[2], Nelson Yee[3], and Si-yang Zheng[2]

[1]Binghamton University, USA, [2]Pennsylvania State University, USA, and [3]Penn Sate College of Medicine, USA

We develop and fabricate a lipid-nanoprobe functionalized nanostructured silica microdevice to enrich nanoscale extracellular vesicles (nEV) from clinical samples for potential cancer diagnostics and treatment monitoring applications. This novel technology utilizes several nEV capturing mechanisms in a low cost, point-of-care, one-step platform to optimize the overall approach and nEV capture efficiency.

Session T2E - Fabrication Technologies II

11:15 - 11:30

T2E.001 A NOVEL METHOD FOR MEMS WAFER-LEVEL PACKAGING: SELECTIVE AND RAPID INDUCTION HEATING FOR COPPER-TIN SLID BONDING

Christian Hofmann[1], Alexander Froehlich[2], Jonas Kimme[2], Maik Wiemer[1], and Thomas Otto[1,2]

[1]Fraunhofer ENAS, GERMANY and [2]Chemnitz University of Technology, GERMANY

A novel method for selective and energy-efficient induction heating of Cu-Sn intermediate layers is presented to support solid-liquid interdiffusion (SLID) bonding at wafer-level. Technological challenges include the coil design for homogeneous heat distribution, the use of high-frequency electromagnetic fields up to frequencies of 2 MHz and the integration of the induction equipment into an industrial waferbond system. Thus, bonding times and pressures could be significantly reduced.

11:30 - 11:45

T2E.002 CHARACTERIZATION OF ORIENTATION-DEPENDENT ETCHING PROPERTIES AND SURFACE MORPHOLOGY OF SAPPHIRE CRYSTAL IN WET ETCHING

Yan. Xing[1], Zhiyue. Guo[1], Guorong Wu[1], and Miguel A. Gosalvez[2]

[1]Southeast University, CHINA and [2]University of the Basque Country, SPAIN

This paper investigates the measurement of the overall orientation dependence of the etch rate for sapphire under different etchant. The etch rate distribution of sapphire is quite different from other trigonal crystal materials. Surface morphology and roughness strongly depends on the crystallographic orientation. The overall etch rate distribution successfully explains the transient and stable structural facets appearing on the micro structures during anisotropic etching of sapphire.

11:45 - 12:00

T2E.003 MOLDING/ENCAPSULATION/INTEGRATION APPROACH FOR TACTILE-BUMP AND SENSING-INTERFACE OF INDUCTIVE TACTILE SENSOR

Sheng-Kai Yeh and Weileun Fang

National Tsing Hua University, TAIWAN

This study presents a novel approach to realize tactile-bump and sensing-interface for inductive tactile sensor. The proposed approach offers three merits for the inductive tactile sensor: (1) chrome steel ball self-assembled/fixed in Si cavity for polymer molding, (2) tactile-bump and MPC sensing-interface integrated in Si cavity by polymer molding, and (3) polymers of different properties integrated using multi steps molding processes.

12:00 - 12:15

T2E.004 A GENERIC CMOS COMPATIBLE PIEZOELECTRIC MULTILAYER ACTUATOR APPROACH BASED ON PERMANENT FERROELECTRIC POLARIZATION INVERSION IN $AL_{1-X}SC_XN$

Simon Fichtner[1,2], Dirk Kaden[1], Fabian Lofink[1], and Bernhard Wagner[1,2]

[1]Fraunhofer ISIT, GERMANY and [2]University of Kiel, GERMANY

Based on the discovery of ferroelectric polarization inversion in piezoelectric AlScN thin films, this paper presents a double layer actuator stack configuration, which demonstrates that the inherent advantages of piezoelectric Al(Sc)N, like CMOS compatibility, stability and linearity can be combined with the advantages of classical ferroelectric multilayers actuators to achieve superior strain output for piezoelectric MEMS actuators with a generic integration approach.

12:15 - 12:45 **Invited Speaker**

T2E.005 EVOLVING FUNCTIONALITY IN DISORDERED NANOSYSTEMS

Wilfred G. van der Wiel

University of Twente, THE NETHERLANDS

Natural and man-made information processing systems differ greatly. Evolution has resulted in living systems that utilize whatever physical properties are exploitable to enhance the fitness for survival. Nature thereby exploits the emergent properties and massive parallelism of highly interconnected networks of locally active components. Man-made computers, however, are based on circuits of functional units, following rigid design rules. In conventional computational paradigms, potentially exploitable physical processes to solve a problem, are possibly left out. Here, we propose to manipulate physical systems using computer-controlled evolution, to take full advantage of the computational power of nanomaterials.

12:45 - 14:30 **Lunch on Own**

13:30 - 14:30 **Industrial Stage Session 2 (Exhibit Hall)**

2a SPTS Technologies LTD, UK
2b Robert Bosch GmbH, GERMANY
2c IntelliSense Software Corp., USA
2d Nanoscribe GmbH, GERMANY

14:30 - 16:30 **Poster Session T3P and Exhibit Inspection (refreshments will be served)**
Poster presentations are listed by topic category with their assigned number starting on page 42.

Session T4A - In-Vivo Sensing

16:30 - 16:45

T4A.001 BIODEGRADABLE POLYMER MICRO ACTUATOR WITH MULTI-DEGREES OF FREEDOM MOTION AND MULTI-STAGE RESPONSE FOR COMPLETE IMPLANTABLE MEDICAL DEVICE AND ROBOTS

Yoshinori Inoue[1,2], Shigeki Narushima[1], Masashi Ikeuchi[1], and Koji Ikuta[1,2]
[1]University of Tokyo, JAPAN and [2]Osaka University, JAPAN

We developed a two-dimensional actuator made of biodegradable polymer which could two step movement due to two stages response of the biodegradable reaction. The first stage occurs within several hours or days and the second one starts from several weeks or several months. This unique feature of biodegradable polymer can drastically upgrade the ability of the biodegradable polymer for the implantable medical device such as mass volume of anticancer drug for both long and short term ejection.

16:45 - 17:00

T4A.002 A WIRELESS FLEXIBLE WEARABLE BIOPOTENTIAL ACQUISITION SYSTEM UTILIZING PARYLENE BASED MICRONEEDLE ARRAY

Dong Huang[1], Hancong Wang[2], Junshi Li[1], Yufeng Chen[1], and Zhihong Li[1]
[1]Peking University, CHINA and [2]University of Electronic Science and Technology of China, CHINA

This paper reports a flexible wearable patch integrated with parylene-based microneedle array (MNA) and signal acquisition f-PCB circuit for long-term biopotential monitoring. The MNA can penetrate high-resistance stratum corneum to achieve low-impedance skin-electrode contact. The flexible device can contact with soft and curved body surface compactly. Furthermore, the circuit and MNAs were integrated and minimized to a small patch, leading to increased wearability.

17:00 - 17:15

T4A.003 FLOATING 5-µM-DIAMETER NEEDLE FOR LOW INVASIVE CHRONIC RECORDING

Koji Yamashita[1], Hirohito Sawahata[2], Shota Yamagiwa[1], Rika Numano[1], Kowa Koida[1], and Takeshi Kawano[1]
[1]Toyohashi University of Technology, JAPAN and
[2]National Institute of Advanced Industrial Science and Technology (AIST), JAPAN

We propose a surgical procedure of <5-µm-diameter microneedle-electrode for chronic neuronal recording. The needle-electrode assembled on an 1 mm square device-platform was packaged with a flexible wire as a 'floating electrode' on the brain tissue. The electrode device, which was placed on a mouse's cortex via melting wax, enabled recording neuronal activities in vivo. In addition,the proposed floating electrode reduced the tissue damage in the implantation, compared to the conventional way.

17:15 - 17:30

T4A.004 FABRICATION OF CONTACT LENS DEVICE WITH INTEGRATED MICROTUBES FOR IN SITU EXTENDED DRUG DELIVERY FOR OCULAR DISEASE TREATMENT

Xiaoke Ding, Chao Song, and Long Que
Iowa State University, USA

Drug delivery is a difficult task in ocular therapeutics. For instance, only <1% of a topically administered drug reaches the aqueous humor. We report a new type of contact lens device with integrated microtubes as drug containers, which could provide a simple, noninvasive, extended drug release up to 40 days with higher bioavailability and lower risk for adverse effects.

17:30 - 17:45

T4A.005 TESTING A MULTI-SENSOR SYSTEM FOR HYDROCEPHALUS MONITORING IN EXTERNAL VENTRICULAR DRAINS

Trevor Hudson[1], Alexander Baldwin[1], Eisha Christian[1], J. Gordon McComb[2], and Ellis Meng[1]
[1]University of Southern California, USA and [2]Children's Hospital Los Angeles, USA

We report a multisensor system for monitoring cerebrospinal fluid (CSF) dynamics in hydrocephalus shunts. Flow and biofouling sensors based on electrochemical impedance transduction were combined into a single microfabricated die. Sensors were validated in external ventricular drains with CSF from human patients in preparation for subsequent clinical studies. The multisensor module was combined with custom electronics for impedance measurement and data collection.

17:45 - 18:00

T4A.006 INTEGRATED CAPSULE SYSTEM FOR GASTROINITESTINAL PH TRIGGERED SAMPLING AND SENSING

George E. Banis, Luke A. Beardslee, Justin M. Stine, Rajendra Mayavan Sathyam, and Reza Ghodssi
University of Maryland, USA

We report an integrated capsule sensing system utilizing a hybrid packaging scheme for detecting pancreatic lipase in pH-specific regions within the human gut. The system uses capacitive sensors that wirelessly interface with a mobile device. The sensors are coated with triglyceride films that insulate the surface and degrade in response to lipase. Furthermore, the capsule utilizes a 3D printed packaging strategy, compatible with different materials for triggered opening of the sensing chamber.

Session T4B - Hydrogen Sensing

16:30 - 16:45

T4B.001 SYNERGISTIC ENHANCEMENT EFFECT OF PALLADIUM-SILVER ALLOY NANOPARTICLE CATALYSTS TOWARDS HIGH-SENSITIVE HYDROGEN DETECTION

Dongsheng Xu[1,2], Dan Zheng[2], Pengcheng Xu[1], Ying Chen[1], and Xinxin Li[1]
[1]Chinese Academy of Sciences (CAS), CHINA and [2]Shanghai Institute of Technology, CHINA

The synergistic enhancement effect of PdAg alloy nanoparticle (NP) catalysts is studied. To form a PdAg enhanced ZnO chemiresistive sensor, ZnO nanowires array is firstly grown onto an integrated MEMS chip and then, PdAg NPs are homogeneously self-assembled onto the surface of ZnO nanowires. Our sensor exhibits highly sensitive to ppm-level H2. Compared with single Pd or Ag NPs, PdAg NPs show much higher catalytic activity to H2.

16:45 - 17:00

T4B.002 A CMOS-BASED THERMO-ELECTROCATALYTIC GAS SENSOR FOR SELECTIVE AND LOW-LEVEL DETECTION OF CARBON MONOXIDE AND HYDROGEN

Claudio Zuliani[1], Richard Hopper[1], Marco Musto[1], Andrea De Luca[2], Claudio Falco[2], and Florin Udrea[2]
[1]ams Sensors UK, UK and [2]University of Cambridge, UK

We demonstrated the use of a CMOS-based thermo-electrocatalytic gas sensor for the selective detection of hydrogen and carbon monoxide in the ppm range. We also showed that the selectivity of the TE sensor towards a gas can be tuned by selecting the appropriate catalyst and by controlling the operational temperature. This type of sensor may offer improved selectivity, lower power consumption and enhanced reliability compared to more widely commercialized metal oxide chemiresistive gas sensors.

17:00 - 17:15

T4B.003 HIGHLY SENSITIVE AND SELECTIVE HYDROGEN GAS SENSOR WITH PLATINUM NANOPARTICLES LINKED BY 4,4''-DIAMINO-P-TERPHENYL (DATER)

Anmona S. Pranti, Daniel Loof, Sebastian Kunz, Volkmar Zielasek, Marcus Bäumer, and Walter Lang
University of Bremen, GERMANY

We have developed a highly sensitive combustible gas sensor for detecting hydrogen selectively against other combustible gases. For the first time we have used 4,4''-Diamino-p-terphenyl (DATER) linked Pt nanoparticles for hydrogen detection. The sensor shows linear characteristics with hydrogen concentration and has very high sensitivity, 31 mV for 0.1% H_2. It consumes extremely low power, 14 mW at 90 °C operating temperature. The sensor has no cross-sensitivity to methane and ethane.

17:15 - 17:30

T4B.004 HYDROGEN ION IMAGE SENSOR WITH BARREL-ARRAY DIFFUSION SUPPRESSOR AND HIPPOCAMPAL SLICE IMAGING

Yuuta Ogaeri[1], Chinatsu Kawakami[1], Takeshi Hizawa[1], Eiji Shigetomi[2], Youichi Shinozaki[2], Tatsuya Iwata[1], Toshihiko Noda[1], Kazuhiro Takahashi[1], Schuichi Koizumi[2], and Kazuaki Sawada[1]
[1]Toyohashi University of Technology, JAPAN and [2]University of Yamanashi, JAPAN

An ion image sensor is an important tool to observe two-dimensional information of a living body in chemically and dynamically. We proposes novel approach to enhance spatial resolution of the ion image sensor for the first time. We introduced a barrel-array to suppress lateral diffusion of measurement target ion on the surface of the ion image sensor. Micro barrel-array with high aspect ratio was fabricated on the ion image sensor using SU-8.

17:30 - 17:45

T4B.005 SELF-POWERED, ULTRA-RELIABLE HYDROGEN SENSOR EXPLOITING CHEMOMECHANICAL NANO-TRANSDUCER AND SOLAR-CELL

Min-Ho Seo, Kyungnam Kang, Jae-Shin Lee, Yongrok Jeong, Seunghye Lee, Inkyu Park, and Jun-Bo Yoon
Korea Advanced Institute of Science and Technology (KAIST), KOREA

We firstly reports a highly reliable self-powered hydrogen (H2) sensor employing a palladium (Pd)-based nano-transducer. The developed sensor is based-on a novel chemomechanical mechanism of the Pd nano-transducer and is operated by a solar-cell. We theoretically and experimentally demonstrated that the proposed device can achieve highly durable operation under a wide range of H2-concentration with remarkable sensitivity (3.1% at 2%-H2) and response-time (111s at 2%-H2) without external power.

17:45 - 18:00

T4B.006 INTEGRATED RESONANT DUAL-MICROCANTILEVERS COMBINED SENSOR WITH ACCURATE IDENTIFICATION AND HIGHLY-SENSITIVE DETECTION TO H_2S GAS

Lei Tang[1,2], Pengcheng Xu[1], Ming Li[1], Haitao Yu[1], and Xinxin Li[1]
[1]Chinese Academy of Sciences (CAS), CHINA and [2]Shanghai Normal University, CHINA

This paper shows a novel integrated resonant dual-microcantilevers combined gas sensor which can identify and detect trace-level H2S. With two kinds of specially designed sensing materials loaded onto the dual-microcantilevers respectively, the experiments show that the sensor can distinguish H2S from a variety of common gases, and the detection limit to H2S is as sensitive as a few ppb.

Session T4C - Energy & Power MEMS I

16:30 - 16:45

T4C.001 STUDY ON THE INFLUENCE OF FERROELECTRIC MATERIALS ON THE OUTPUT PERFORMANCE OF TRIBOELECTRIC NANOGENERATORS

Xin Chen[1], Lingxiao Gao[1], Junfei Chen[1], Mengke Qi[1], Dongxiao Li[1], Shaokun Zeng[2], and Xiaojing Mu[1]
[1]Chongqing University, CHINA and [2]Chongqing University of Science and Technology, CHINA

We present the marvelous ability of ferroelectric materials to enhance the output performance of the triboelectric nanogenerators (TENG). Here, we fuse the PZT and PVDF into the traditional TENG, improve the output performance successfully by a nondestructive and portable way. Providing a new direction to optimize the output performance of the TENG.

16:45 - 17:00

T4C.002 A CONDITIONING SYSTEM FOR HIGH-VOLTAGE ELECTROSTATIC/TRIBOELECTRIC ENERGY HARVESTERS USING BENNET DOUBLER AND SELF-ACTUATED HYSTERESIS SWITCH

Hemin Zhang[1], Dimitri Galayko[2], and Philippe Basset[1]
[1]Univerisity Paris-Est, FRANCE and [2]Sorbonne Université, FRANCE

We propose for the first time a full self-powered conditioning system to efficiently manage the very high-voltages of electrostatic /triboelectric energy harvesters. It includes an unstable charge pump (a Bennet doubler), a novel self-actuated electrostatic switch having a narrow hysteresis and a DC-DC Buck converter. With this system, the converted energy per cycle is improved by 24 times compared to a classical full-wave diode bridge, under a voltage compatible with commercial regulators.

17:00 - 17:15

T4C.003 MEMS PIEZOELECTRIC ENERGY HARVESTER POWERED WIRELESS SENSOR MODULE DRIVEN BY NOISY BASE EXCITATION

Sijun Du[1,2], Yu Jia[3], Emmanuelle Arroyo[1], Sandra Fernandez[4], Stephen T. Riches[5], and Ashwin A. Seshia[1]
[1]University of Cambridge, UK, [2]University of California, Berkeley, [3]Aston, University, UK,
[4]McLaren Applied Technologies, UK, and [5]Tribus-D, UK

This paper presents a wireless sensor system powered by a MEMS piezoelectric vibration energy harvester excited by band-limited large amplitude noisy vibration characteristic of an automotive application.

17:15 - 17:30

T4C.004 BROADBAND ENERGY HARVESTING USING BI-STABILITY AND FREQUENCY UP-CONVERSION FOR SELF-POWERED SENSING IN INTERNET OF THINGS

Hailing Fu, Zahra Sharif Khodaei, and M.H. Ferri Aliabadi
Imperial College London, UK

A bio-inspired host-parasite energy harvesting is designed, fabricated and experimentally validated for self-powered sensing applications. A host beam is set to be buckled; two parasitic beams are mounted on the host beam and plucked by it during an interwell motion. The low-frequency host beam vibration is up-converted to the parasitic beams' vibration at resonance. The system was validated experimentally, showing the capability to harness low-frequency, low-amplitude random vibrations.

17:30 - 17:45

T4C.005 A MEMS-BASED BI-STABLE ELECTROMAGNETIC ENERGY HARVESTER WITH A FULLY INTEGRATED NICKEL-BASED CLOSED MAGNETIC CIRCUIT

Kai Wang, Xuhan Dai, Xiaojian Xiang, Guifu Ding, and Xiaolin Zhao
Shanghai Jiao Tong University, CHINA

We present a MEMS-based bi-stable electromagnetic energy harvester with polarity-reversible integrated closed magnetic circuit in micro-scale to maximize the flux variation rate. Bi-stable configuration with shallow potential barrier is accurately achieved to trigger inter-well oscillation and sustain in high energy orbit by monolithic micro-fabrication technology. Test results show that, at the acceleration of 1.5 g, dramatic improvement in bandwidth and power output are simultaneously obtained.

17:45 - 18:00

T4C.006 A 1.3 MILLIWATTS ELECTROSTATIC VIBRATIONAL ENERGY HARVESTER WITH MINIMAL REACTIVE POWER THROUGH REDUCED INTERNAL STRAY CAPACITANCES

Hiroaki Honma, Yukiya Tohyama, and Hiroshi Toshiyoshi
University of Tokyo, JAPAN

We report on a methodology to enhance the output power and power density of vibrational MEMS energy harvesters by reducing the reactive power within the device. An SOI wafer with a relatively thick BOX layer is used to reduce the internal stray capacitance. The active power is 2.9-fold improved by increasing the BOX layer from 1 micron to 3 microns, resulting in a power enhancement to 1.3 mW, without changing the device design or footprint.

Session T4D - Wearable Sensors

16:30 - 16:45

T4D.001 HIGHLY SENSITIVE AND RELIABLE STRAIN SENSOR BASED ON MoS_2-DECORATED LASER-SCRIBED GRAPHENE FOR WEARABLE ELECTRONICS

Ashok Chhetry, Hyosang Yoon, Md. Sharifuzzaman, and Jae Y. Park
Kwangwoon University, KOREA

We propose a novel approach for the fabrication of a highly sensitive and reliable strain sensor based on MoS_2-decorated laser-scribed graphene for flexible and wearable electronics. Laser-thinning of multilayered MoS_2 coated on commercial polyimide film enables three-dimensional hierarchical porous graphene network decorated with MoS_2. The technique offers a simple, facile and scalable approach for the fabrication of high-performance strain sensor.

16:45 - 17:00

T4D.002 HIGHLY SENSITIVE CHARGE-COUPLE DEVICE-BASED FLEXIBLE PH SENSOR FOR WEARABLE HEALTH CARE APPLICATION

Mao Shiomi, Shogo Nakata, Yusuke Fujita, Takayuki Arie, Seiji Akita, and Kuniharu Takei
Osaka Prefecture University, JAPAN

This study proposes a flexible charge-coupled device (CCD) for high sensitive pH detection integrated with a solution-based temperature sensor. By optimizing the device design and structures, pH sensitivity more than 240 mV/pH is realized by repeating the cycles, which is higher than the one defined as Nernst theory. In addition to the fundamental characteristics of the pH sensor, real-time sweat pH and skin temperature monitoring are successfully conducted by attaching the device on a body.

17:00 - 17:15

T4D.003 WIDE RANGE-SENSITIVE, BENDING-INSENSITIVE PRESSURE DETECTION AND APPLICATION TO WEARABLE HEALTHCARE DEVICE

Seunghwan Kim[1], Morteza Amjadi[2], Tae-Ik Lee[1], Yongrok Jeong[1], Donguk Kwon[3], Min Seong Kim[1], Kyuyoung Kim[1], Taek-Soo Kim[1], Yong Suk Oh[1,3], and Inkyu Park[1]
[1]Korea Advanced Institute of Science and Technology (KAIST), KOREA, [2]Max-Planck Institute for Intelligent Systems, GERMANY and [3]Northwestern University, USA

We report a wide range-sensitive, bending-insensitive pressure sensor based on a carbon nanotube (CNT)-coated thin porous elastomer and its wearable healthcare application. The pressure sensor exhibits a very wide sensing range from ultralow to high pressure (50Pa~1MPa) with favorable sensing performances and bending-insensitive pressure-sensing capability. Finally, we demonstrated a flexible foot insole for real-time monitoring of foot plantar pressure distribution.

17:15 - 17:30

T4D.004 TRANSIENT EPIDERMAL ELECTRONIC AND OPTOELECTRONIC DEVICES FOR MULTIDIMENSIONAL PHYSIOLOGICAL MONITORING

Yujia Zhang[1], Long Sun[1], Shan Zhang[1], Feihong Xu[2], and Tiger H. Tao[1,2,3]
[1]Chinese Academy of Sciences (CAS), CHINA, [2]Northwestern Polytechnic University, CHINA, and [3]Shanghai Technical University, CHINA

We report a flexible epidermal transient electronic system, including wearable electrodes, electronics and optoelectronics, by utilizing silk/glycerol (SG) blended films. As a proof of concept, a wearable SG-based electrode and a SG-based optoelectronic monitor are built for multidimensional physiological monitoring. This study addresses the seamless confluence of biomaterial and epidermal devices, which will pave the way for the harmonized integration of electronics/optics into human.

17:30 - 17:45

T4D.005 A FLEXIBLE PRESSURE SENSOR WITH HIGH SENSITIVITY AND BROAD MEASURING RANGE

Shuai Zhao and Rong Zhu
Tsinghua University, CHINA

We report a novel flexible pressure sensor based on piezo-thermic transduction principle, using an innovatively designed porous Ag/PDMS sponge with a graded porosity. The sensor exhibits a high sensitivity, a low detection limit, and a wide range, allowing monitoring significantly different human signals from subtle wrist pulse to foot tapping pressure with a single device.

17:45 - 18:00

T4D.006 THERMAL IMPRINTED SELF-POWERED TRIBOELECTRIC FLEXIBLE SENSOR FOR SIGN LANGUAGE TRANSLATION

Pukar Maharjan, Trilochan Bhatta, and Jae Yeong Park
Kwangwoon University, KOREA

Herein, we report the first self-powered thermal imprinted flexible triboelectric sensors (TIFS) for sign language translation (SLT). Innovatively coupling the contact electrification effect with a structure inspired form human skin, the as-fabricated sensor exhibits a superior sensitivity of 0.5 V kPa-1 with a fast response time less than 20 ms. A fully wireless SLT system including 14 TIFSs was demonstrated converting different signs into voice and text on smartphone, successfully.

Session T4E - Assembly & Self-Assembly

16:30 - 17:00 **Invited Speaker**

T4E.001 PRECISE PLACEMENT OF NANO-SPHERES AND -WIRES UTILIZING BROWNIAN MOTORS IN A TUNABLE NANOFLUIDIC CONFINEMENT

Armin W. Knoll, Christian Schwemmer, Stefan Fringes, and Colin Rawlings
IBM Research, SWITZERLAND

We demonstrate a novel concept to transport and immobilize particles at defined target positions on a substrate. The high level of control we gain over the particles relies on a lithographically defined energy landscape in a tunable nanofluidic slit. The landscape allows us to selectively transport the particles to the target location employing Brownian motor concepts. At the target location electrostatic traps are used to localize the particles and to force them into the correct orientation. We demonstrate the deposition of nano-spheres, rods and wires onto pre-defined electrodes.

17:00 - 17:15

T4E.003 PROGRAMMABLE MICRO-OBJECT ASSEMBLY WITH TRANSFER

Eugene M. Chow
PARC, USA

We present an integrated microassembly and transfer process for micro-object integration at fine scale and over large areas. Parallel, automated, directed electrostatic assembly is used to sort, translate, place and orient parts. The approach aims to create a xerographic like printer process for enabling next generation sensor arrays, as well as complex, heterogeneous systems with millions of small parts.

17:15 - 17:30

T4E.004 HIGH-ASPECT-RATIO NEEDLE-SHAPED MOLD FABRICATION USING ROSENSWEIG INSTABILITY IN FERROFLUIDS

Babak Assadsangabi, Sayed Mohammad Hashem Jayhooni, Tynan Stack, and Kenichi Takahata
University of British Columbia, CANADA

This paper reports a simple cleanroom-free fabrication technique to create high-aspect-ratio needle-like solid mold structures using magnetic self-assembly of ferrofluids under the Rosensweig instability of the fluids. The presented fabrication method provides precise control over the aspect ratio, sharpness, and spatial arrangement of the mold structures in array on the substrate, which makes it an attractive approach to the application for microneedle production.

17:30 - 17:45

T4E.005 RAPID ASSEMBLY OF DNA ORIGAMI IN MICROFLUIDIC TEMPERATURE GRADIENT

Kentaro Kawai[1], Keita Hara[1], Ryota Nakamura[1], Kenta Arima[1], Kazuya Yamamura[1], and Osamu Tabata[2]
[1]Osaka University, JAPAN and [2]Kyoto University, JAPAN

We present an effect of temperature distribution during a rapid folding of DNA nanostructures, called DNA origami. Based on results of computational fluid dynamics simulation, time-dependent temperature distribution in microtube effects the yield of DNA origami. We confirmed rapid self-assembly of DNA nanostructures in microfluidic channel.

17:45 - 18:00

T4E.006 FLUIDIC SELF-ASSEMBLY TRANSFER TECHNOLOGY FOR MICRO-LED DISPLAY

Seongkyu Cho[1], Daewon Lee[1], and Sunghoon Kwon[1,2]
[1]Seoul National University, KOREA and [2]Seoul National University Hospital, KOREA

We developed and optimized fluidic self-assembly (FSA), a fast and cost effective microchip transfer technology for Micro-LED displays. More than 19,000 blue GaN microchips with 45um in diameter were precisely assembled by eutectic alloy bonding with 99.90% yield. Surfactant was added in the assembly solution to dramatically increase the assembly yield and design of the chip was optimized for accurate one-by-one assembly.

18:00 **Adjourn for the Day**

Industry Start-Up Session (RSVP required)

18:15 -18:35 Keynote Speaker

T5D.001 THE NEW RISE OF HARD TECH STARTUPS - PERSPECTIVES OF A VENTURE CAPITAL INVESTOR
Steffen Wagner, CEO, Co-Founder
investiere - Venture Capital, SWITZERLAND

Hardware startups face the laws of physics. Unlike their digital siblings, they can't move fast and break things, they must tread carefully. Identifying commercial applications and improving prototypes is a lengthy process, production at scale necessitates mountains of capital, investors are hard to find. Compared to social networks and their lofty valuations, challenges and potential rewards seem to be out of balance. So why bother? Well, software might be eating the world, but to build a new world we need hardware. As a venture capitalist who loves hardtech, I will share some Dos and Don'ts for hardtech entrepreneurs.

18:35 - 18:45

T5D.002 A UNIVERSITY SPIN-OFF EXPERIENCE: FROM THE IDEA TO THE FIRST SAMPLES
Andrea De Luca
Flusso, UK

In the talk I will be sharing my personal experience as co-founder and CEO of Flusso, a spin-off from the University of Cambridge devoted to commercialization of CMOS MEMS flow sensing technologies. The talk will be covering the motivations that led to the creation of Flusso (right after finishing my Ph.D.) as well as the challenges I faced (and I am still facing!) in moving from an academic position to an industrial one. Also a brief overview of our technologies will be presented.

18:45 - 18:55

T5D.003 memetis - FROM MODEL TRAINS TO LAB ON A CHIP
Marcel Gültig
memetis GmbH, GERMANY

memetis develops foil-based miniature actuators from shape memory alloys (SMA). Foil-based SMA miniature actuators enable high switching forces with better integration capacities and greater flexibility compared to available, wire-based solutions. memetis has the expertise to quickly adapt its actuators to market and customer requirements by specific micro-structuring procedures and specially adapted rapid manufacturing technology. Due to the expanded application spectrum, memetis SMA miniature actuators are used in a variety of innovative industries, such as biotechnology or medical technology.

18:55 - 19:05

T5D.004 MuVaP: HIGH-PERFORMANCE MICRO-VALVES-AND-PUMPS
Ardavan Shabanian
muVaP GmbH, GERMANY

Utilizing our novel buckling piezo-membrane-actuators, we have developed a disruptive technology, muVaP, which is a high performance micro-Valve-and-Pump. Part of this work was presented at previous Transducers conference as "THE DEFORMABLE VALVE PUMP (DVP)." With a cross section of only 23x23 mm, as a pump it can deliver an outstanding flowrate of 44 ml/min at only 200 mW of power consumption. As a valve it can close against 2 bars of pressure and allow for a flow of 8.5 l/min, with an actuation energy of only 7 mJ. As a team of four founders, we have just acquired over 1 Million Euro of Start-up-grant from the German-Federal-Ministry-for-Economic-Affairs-and-Energy to bring this technology to the market, which enables us to maneuver freely in broad domain of microfluidics, within a wide range of medical and industrial applications, depending on our potential future collaborators; what can make us particularly interesting for your participants!

19:05 - 19:15

T5D.005 MEMS-CASTING TECHNOLOGY AND ITS APPLICATIONS
Jiebin Gu
Shanghai MCT semiconductors, Co., Ltd., CHINA

Thick metal deposition on wafer is a critical process for Advanced Packaging, MEMS, etc. Currently electroplating is almost the only option. As a start-up, we are developing a unique metal process which is named MEMS-Casting. Casting as a thousand years old metalworking process is capable to fabricate complex 3D metal structures; while MEMS as a decades old technology is good at fabricating micro-scale mechanical parts. By combination of the two technologies, metal structures in tens of microns can be fabricated by batch on wafer-level. As a substitution and supplemental of electroplating, this technology can be used for Advanced Packaging, such as TSV/TGV via filling; solenoid coils for MEMS fluxgate sensor and Integrated Passive Device (IPD), etc. As a start-up, we focus our work on R&D of the MEMS-Casting process and its specific equipment. Currently, we provide this technology as a service for customs who need this type of thick metal.

19:15 - 19:25

T5D.006 FILM BULK ACOUSTIC RESONATOR (FBAR) AS NEXT GENERATION MULTI-APPLICATION SENSOR
Mario De Miguel Ramos
Sorex Sensors Ltd., UK

FBAR MEMS technology is a scaled application for use as a replacement for surface acoustic wave (SAW) filters in most mobile applications. Sorex Sensors has used this technology to develop an ultra high sensitivity mass sensor. The FBAR when put in resonance can detect changes in mass down to the femto-gram range - able to detect a single virus or complex molecules. The sensor MEMS production has been transfered into an 9-inch foundry and the company has started to gain commercial traction in a number of interesting hight growth market verticals including atomic layer deposition (ALD) systems, vehicle emission testing, air quality sensing and fresh produce tranportation and storage.

19:25 - 19:35

T5D.007 MEMS-BASED SPECTROCHIP IMPLEMENTED TO HOME HEALTHCARE, FOOD SAFETY, AND BLOCKCHAIN APPLICATION

Cheng-Hao Ko
Spectrochip Inc., TAIWAN

Enabling A Powerful Worldwide Care Intellignet Cloud With SpectroChip Based on our SpectroChip technology, we can provide instant personal care analysis system. SpectroChip can be embedded in handheld devices or in smart phones to perform spectral sensing of test strips and reagents, which can reveal the personal biological data as well as all sorts of test items. Tests include personal care items, e.g., urine, blood, saliva, pregnancy, tears; food safety inspections, e.g., water quality (pH, Chlorine, bacterial, heavy metal, etc.), meat products (Nitride, freshness, pigment, infections,SO2, etc.), vegetable and fruits (waste oil, acid, etc.), dairy products, condiments, wine, etc. Hundreds to thousands items can be detected based on current available test strips and reagents. When the spectral sensors are widely used, big data can be collected and analyzed. AI technology can play a key role in analyzing these big data and provide useful, critical and precision information to the users. Our technology integrates IoT SiP spectrochip module, computation algorithm, Apps, spectrochip IoT intelligent edge and Intelligent cloud. A total solution is ready to be incorporated into any smart phone and handheld device systems. With the incorporation of our SpectroChip platform, hundreds to thousands items related to personal and home care can be added to the worldwide care analysis cloud.

19:35 – 19:50 Invited Speaker

T5D.008 MEMS, SENSORS, AND MICROTECHNOLOGY STARTUPS: CURRENT AND EMERGING TRENDS

Mike Pinelis
Microtech Ventures, Inc.

This has been an exciting time for MEMS, sensors, and microtechnology companies with many next-generation devices getting into the marketplace. There are many new applications in the areas of advanced medical devices, autonomous vehicles, environmental monitoring, and robotics. Every week, at least 3-4 MEMS and sensors startups are getting funded. We are currently tracking more than 350 recently funded startups working on MEMS and sensors technologies. Plus, there are thousands of groundbreaking innovations being developed in the academia and industry R&D labs. Around the globe, people are enjoying an increasingly higher quality of life enabled by these technologies. In this talk, we'll provide an overview of the MEMS and sensors startup activities, and also outline the main emerging trends.

19:50 - 20:30 **Mixer**

Wednesday, 26 June

08:00 **Continental Breakfast in Exhibit Hall**

08:30 - 09:15 **Plenary Presentation III**

W1A.P03 FROM ARECIBO TO FAST, THE KINSHIP BETWEEN IMPOSSIBLE DREAMS

Di Li
Chinese Academy of Sciences (CAS), CHINA

The 300-meter Arecibo telescope is one of the technical wonders of the 20thcentury and had been the world leader in absolute sensitivity in deca-centimeter bands for more than half a century, until Sep. 25, 2016, the dedication of the Five-hundred-meter Aperture Spherical radio Telescope (FAST), which has two to three times the sensitivity and one-order-of-magnitude higher survey speed. Still under commissioning, FAST (Nan et al. 2011) has discovered >60 new pulsars and realized an unprecedented commensal-survey mode (Li et al. 2018). We strive to take the next step toward space through innovative radio technologies.

09:15 - 09:30 **EUROSENSORS 2020 Announcement**

09:30 - 09:45 **Transition**

Session W1A - Bio Mechanics

09:45 - 10:00

W1A.001 A MONOLITHIC POLYDIMETHYLSILOXANE PLATFORM FOR ZOOSPORE CAPTURE, GERMINATION AND SINGLE HYPHA FORCE SENSING

Yiling Sun, Ayelen Tayagui, Ashley Garrill, and Volker Nock
University of Canterbury, NEW ZEALAND

We report the development, fabrication and use of a lab-on-a-chip platform combining capture and culture of individual zoospores with integrated force sensing on germinated hyphae. Zoospores of the oomycete *Achlya bisexualis* were trapped and cultured on the device, and the force exerted by hyphae measured using elastomeric micropillars. The platform provides a new tool to help understand the generation of protrusive growth in fungi and oomycetes, and aid the search for new biocontrol agents.

10:00 - 10:15

W1A.002 SHAPE DEFORMATION ANALYSIS OF SINGLE CELL IN 3D TISSUE UNDER MECHANICAL STIMULI

Keitaro Kasahara[1], Yuta Kurashina[2], Shigenori Miura[3], Shogo Miyata[1], and Hiroaki Onoe[1]
[1]Keio University, JAPAN, [2]Tokyo Institute of Technology, JAPAN, and [3]University of Tokyo, JAPAN

We developed an analytical platform to investigate the mechanism of maturation induced by mechanical stimuli in in vitro tissues. The system is capable of live-imaging cells in 3D tissues at a single cell level under mechanical stimulation. We succeeded in imaging various shapes of cells in 3D tissue under mechanical stimuli and found that original shapes of cells affect the direction of the stretch-induced deformation.

10:15 - 10:30

W1A.003 TENSILE CHARACTERIZATION OF THIN BIOMEMBRANE

Shinya Sakuma, Yuhao Gao, Yuichi Murozaki, and Fumihito Arai
Nagoya University, JAPAN

We present the tensile characterization system of biomembranes. Since their thickness is just a few micro-meters, we have the difficulties in handling of the flimsy and small test piece in liquid. To face these challenges, we developed the following novel devices. (1) The force sensor clamp consisting the microfluidic chuck and the water-proof force sensor. (2) The house-designed microcutter to prepare the dumbbell-shaped test piece. (3) The flexible membrane container to handle the test piece.

10:30 - 10:45

W1A.004 A MICROTAS FOR LIQUID SAMPLE BULK MODULUS SCREENING

Xi Zhang, Yao Lu, Menglun Zhang, Hongxiang Zhang, Qingrui Yang, and Wei Pang
Tianjin University, CHINA

We presents a micro total analysis system integrating digital microfluidics, acoustic wave microsensors and electronic circuits for rapid sample screening based on liquid bulk modulus measurement. The microsystem is designed for in-field analysis devices where a number of liquid samples need to be processed in a short time.

Session W1B - Accelerometers and Gyros I

09:45 - 10:15 **Invited Speaker**

W1B.001 FREQUENCY MODULATED MEMS GYROSCOPES: RECENT DEVELOPMENTS, CHALLENGES AND OUTLOOK

Giacomo Langfelder, Paolo Minotti, Valentina Zega, Claudia Comi, Cristiano R. Marra, Mauro Leoncini, and Marco Bestetti
Politecnico di Milano, ITALY

After about ten years of researches by different groups, this work summarizes the various frequency-modulated techniques for microelectromechanical system (MEMS) based gyroscopes. It then focuses on low-power integrated electronics for Lissajous FM rate sensors and on the conditions to guarantee high offset stability over temperature. Recent results in terms of scale-factor drift and offset drift over temperature on a complete Lissajous FM gyroscope with full digital output are reported.

10:15 - 10:30

W1B.003 3-AXIS CATCH-AND-RELEASE GYROSCOPE WITH PANTOGRAPH VIBRATION FOR LOW-POWER AND FAST START-UP APPLICATIONS

Akiko Yuzawa[1], Ryunosuke Gando[1], Kei Masunishi[1], Etsuji Ogawa[1], Hiroki Hiraga[1], Yasushi Tomizawa[1], Tetsuro Itakura[1], and Tamio Ikehashi[2]
[1]Toshiba Corporation, JAPAN and [2]Waseda University, JAPAN

We develop the first 3-axis MEMS gyroscope that employs intermittent free vibration realized by a "Catch-and-Release (CR)" method. This CR operation enables drive power reduction and instant start-up. The fabricated gyroscope with a pantograph structure is shown to have 3-axis sensitivities with <2% cross-axis sensitivities. The consecutive CR operation with release DC voltage at 25V and a high Q factor of 440k at 20 kHz pantograph mode are confirmed.

10:30 - 10:45

W1B.004 A NOVEL MICRO SHELL RESONATOR GYROSCOPE WITH SIXTEEN T-SHAPE MASSES

Wei Li, Xiang Xi, Kun Lu, Yan Shi, Zhanqiang Hou, Yulie Wu, Xuezhong Wu, and Dingbang Xiao
National University of Defense Technology, CHINA

A novel micro shell resonator gyroscope (MSRG) with sixteen T-shape masses is proposed in this paper. we demonstrate the performance of MSRG using out-of-plane capacitive transduction. The MSRG is operated in force-rebalance mode, which demonstrates a scale factor (SF) of 0.112V/(deg/s), an angle random walk (ARW) of 0.035deg/√h and a bias stability of 0.877deg/h.

Session W1C - RF MEMS I

09:45 - 10:00

W1C.001 ANALYTICAL MODEL AND EXPERIMENTS OF PHASE NOISE IN OVEN-CONTROLLED MEMS RESONATORS

Heng Yang, Ke Sun, Binbin Pei, Peng Zhong, and Xinxin Li
Chinese Academy of Sciences (CAS), CHINA

This paper presents an analytical model and experiments of phase noise in oven-controlled MEMS resonators, which shows that the phase noise is dominated by the up-conversion of the thermal noise of the spring constant. The explicit formulation of the 1/f spectra in the resonator is derived by superposition of two relaxation processes: resonator damping, and transient heat conduction. The transient heat conduction is simulated by an equivalent circuit model. The model matches the experiments.

10:00 - 10:15

W1C.002 IMAGING MULTIMODE VIBRATIONS IN HIGH-FREQUENCY ALUMINUM NITRIDE PIEZOELECTRIC NANOMEMBRANE RESONATORS

Hao Jia[1], Matthew H. Matheny[2], Michael L. Roukes[2], and Philip X.-L. Feng[1]
[1]Case Western Reserve University, USA and [2]California Institute of Technology, USA

We report on the first imaging and visualization of the multimode resonant behaviors of aluminum nitride (AlN) piezoelectric nanomembrane resonators, by exploiting a spectromicroscopy technique. High-frequency multimode vibrations up to 33MHz are observed. Brownian motion, driven and nonlinear dynamic vibrations are measured and spatially mapped. Such a multimode AlN device platform holds great promise for ultrasensitive gravimetric detection, mass spectroscopy, and inertial imaging.

10:15 - 10:30

W1C.003 HIGH-Q UHF AND SHF BULK ACOUSTIC WAVE RESONATORS WITH TEN-NANOMETER $HF_{0.5}ZR_{0.5}O_2$ FERROELECTRIC TRANSDUCER

Mayur Ghatge, Glen Walters, Toshikazu Nishida, and Roozbeh Tabrizian
University of Florida, USA

This paper reports high-Q multi-morph BAW resonators with frequencies from 30MHz-13GHz, enabled by 10nm hafnium-zirconium-oxide(HZO) ferroelectric transducer. The 10nm HZO is the thinnest ever-reported transducer and a 12.84GHz HZO-actuated resonator is demonstrated with a Q of ~320. Benefiting from large electromechanical coupling, conformal deposition & CMOS-compatibility, ALD HZO paves the way for frequency scaling and monolithic integration of nano-resonators for 5G mm-wave front-ends.

10:30 - 10:45

W1C.004 A 10 GHZ SINGLE-CRYSTALLINE SCANDIUM-DOPED ALUMINUM NITRIDE LAMB-WAVE RESONATOR

Mingyo Park[1], Zhijian Hao[1], Dea Gyu Kim[1], Andrew Clark[2], Rytis Dargis[2], and Azadeh Ansari[1]
[1]Georgia Institute of Technology, USA and [2]IQE Plc, USA

We report on the first demonstration of Lamb-wave resonators based on single-crystalline Scandium (Sc)-doped AlN films operating at 8-10 GHz. The high effective electromechanical coupling coefficient is achieved due to single crystallinity grown by using molecular beam epitaxy and the 12% Sc-doping. This work proves the superior performance achieved by utilizing single-crystalline Sc-AlN thin films compared to sputter-deposited films in SHF range suitable for 5G filter applications.

Session W1D - Tactile Sensors I

09:45 - 10:00

W1D.001 SIMULTANEOUS MEASUREMENT OF SURFACE TEXTURE AND ELASTICITY USING TACTILE SENSOR WITH DIFFERENTLY PROTRUDED CONTACTOR ARRAY

Kazuki Watatani, Kyohei Terao, Fusao Shimokawa, and Hidekuni Takao
Kagawa University, JAPAN

We developed an array type tactile sensor with differently protruded contactors and a new detection principle for simultaneous measurement of high-resolution surface texture and the elasticity (or softness) of the touching object. In the experiments, surface shape and slip friction of the samples having elasticity of 0.57 to 2.6 MPa were successfully measured. Additionally, simultaneous measurement of their elasticities was also demonstrated for the first time.

10:00 - 10:15

W1D.002 A HIGHLY SENSITIVE CAPACITIVE PRESSURE SENSOR WITH MICRODOME STRUCTURE FOR ROBOT TACTILE DETECTION

Shan Wang, Kuan-Hua Huang, and Yao-Joe Yang
National Taiwan University, TAIWAN

This work presents a highly sensitive capacitive pressure sensor with microdome structures fabricated on biocompatible polydimethylsiloxane (PDMS) films. The capacitive tactile sensor consists of two PDMS layers with interlocked microdome structures, which were patterned by using a nylon membrane filter for enhancing sensitivity. The performance comparison between different structures of capacitor gap was shown. Demonstration of the proposed device installed on robot fingers was also presented.

10:15 - 10:45 **Invited Speaker**

W1D.003 ADVANCEMENTS IN POLYMERIC CAPACITIVE TACTILE SENSORS

Cheng-Yao Lo
National Tsing Hua University, TAIWAN

This paper discloses the recent advancements in capacitive tactile sensors (CTSs) that are mostly composed of polymeric materials: The add-on function of a CTS that supports normal and shear force detection, the angular resolution of a CTS that distinguishes the shear force applied along a specific angle in the xy-plane, the spatial resolution improvement on the CTS, the sensitivity enhancement in both normal and shear force detections, the suppression of detection tolerance generated during fabrication, and the working range expansion of a CTS.

Session W1E - Optical Elements & Systems

09:45 - 10:00

W1E.001 ASSESSMENT OF ADDITIVE MANUFACTURING PROCESSES FOR MONOLITHIC DIFFRACTIVE-REFRACTIVE MICRO-COMPONENTS

Johannes Wolf[1], Susanne Grützner[1], Margit Ferstl[2], Arne Schleunitz[1], and Gabi Grützner[1]
[1]Micro Resist Technology GmbH, GERMANY and [2]Fraunhofer HHI, GERMANY

We propose a novel additive manufacturing process to cost-effectively generate prototypes of hybrid micro-optical components. We combine UV-molding with inkjet printing techniques using the optical polymer inks InkOrmo and InkEpo. This results in an innovative concept to integrate diffractive and refractive elements into one monolithic polymer component with high versatility in micro- and nanoscale geometries. Thus, the novel process enables an easy access to advanced micro-optical designs.

10:00 - 10:15

W1E.002 NEXT GENERATION OF HIGHLY MINIATURIZED BULK-MEMS FABRY-PÉROT FILTERS FOR INFRARED MICROSPECTROMETERS

Martin Ebermann[1], Norbert Neumann[1], Silke Hoppe[1], Karla Hiller[2], Jan Seiler[2], Christian Helke[2], Marco Meinig[3], and Steffen Kurth[3]
[1]InfraTec GmbH, GERMANY, [2]Technische Universität Chemnitz, GERMANY, and [3]Fraunhofer ENAS, GERMANY

We report on the progress in miniaturization of bulk micromachined FP filters and tunable detector modules for the mid infra¬red. The chip size was reduced from 7x7 mm_ to 5x5 mm_, enabling integration into TO5-size detector packages, which is about only one quarter of the formerly used TO8. At the same time a high optical throughput is maintained. An MEMS design with two moveable reflectors is used, which allows for lower actuation voltages and provides negligibly acceleration sensitivity.

10:15 - 10:30

W1E.003 HIGH-RESOLUTION PIEZOELECTRIC MEMS SCANNER FULLY INTEGRATED WITH FOCUS-TUNING AND DRIVING ACTUATORS

Shunsuke Inagaki, Yuki Okamoto, Akio Higo, and Yoshio Mita
University of Tokyo, JAPAN

This study presents a self-deformable MEMS mirror for a focus-tunable MEMS scanner. Piezoelectric actuator was monolithically integrated on a 4 mm-diameter mirror. The focal length can be changed from -120 mm to +140 mm according to the applied DC voltage. The maximum optical scanning angle of the proposed scanner is 26.2°, which meets the demands of high-resolution laser scanning applications.

10:30 - 10:45

W1E.004 WAVEGUIDE GRATING COLOR REFLECTOR USING GERMANIUM TELLURIDE

Mohsen Jafari[1], L. Jay Guo[1], and Mina Rais-Zadeh[1,2]
[1]University of Michigan, USA and [2]NASA JPL, USA

This paper demonstrates a tunable color filter in an optical waveguide grating architecture consisting of a phase change material (Germanium Telluride (GeTe)). Here, the waveguide and the grating resonances were used to enhance the color dynamic of the filter at visible wavelengths when the phase of GeTe is transitioned between the amorphous and crystalline states in response to a heat stimulus.

10:45 - 11:15 **Break and Exhibit Inspection**

Session W2A - Cell on a Chip I

11:15 - 11:30

W2A.001 PAIRING AND ELECTROFUSION OF LIPOSOMES IN A DYNAMIC MICROARRAY DEVICE

Keisuke Sugahara, Sho Takamori, and Shoji Takeuchi
University of Tokyo, JAPAN

In this paper, we present a microfluidic device for electrofusion of liposomes. The device contains hydrodynamic microarray system for pairing liposomes and two microelectrodes for the application of electric field on the paired liposomes. Arraying multiple pairing channels, we demonstrated the electrofusion of paired liposomes in the dynamic microarray structure.

11:30 - 11:45

W2A.002 THERAPEUTIC AND SIDE EFFECTS MODELING OF ELECTROLYTIC CANCER ABLATION THERAPY USING ORGAN-ON-A-CHIP

Moon chul Park[1], Jong man Yoo[2], and Albert Kim[1]
[1]Temple University, USA and [2]Cha University, KOREA

Organoids are 3D cultured stem cells that recapitulate the composition, architecture, and function of its counterparts. Fabricating organoids with 3D-printed microfluidics is a low-cost solution for closing the gap between the pre-clinic test and human trials. In this paper, we present a Multi-Organoid-on-a-Chip system that enables the modeling of electrochemical cancer ablation.

11:45 - 12:00

W2A.003 A MICROFLUIDIC SYSTEM COMBINING VALVE AUTOMATION AND SPHEROID CULTURES TO CHARACTERIZE HEPATIC GLUCOSE METABOLISM DURING HORMONAL STIMULATION

Diana F. Cedillo-Alcántar[1], Gulnaz Stybayeva[1], José M. de Hoyos-Vega[1], Yong Duk Han[2], Jonghoon Choi[2], José L. García-Cordero[1], and Alexander Revzin[2]
[1]Centro de Investigación y de Estudios Avanzados del IPN, MEXICO and [2]Mayo Clinic, USA

A droplet-based biosensing device and micro-tissue cultivation device was integrated into single organ-on-a-chip system for monitoring of the hepatic tissue responses toward fluctuating hormonal stimuli. This system was suited for long-term cultivation of functional hepatocytes and was used for periodic stimulation with hormones, insulin and glucagon. An integrated on-chip bioanalysis module was used to analyze changes in glucose levels and hepatic function in healthy and injured liver cultures.

12:00 - 12:15

W2A.004 IN-DROPLET CELL SEPARATION BASED ON LATERAL DIELECTROPHORESIS RESPONSE

Can Huang, Song-I Han, and Arum Han
Texas A&M Univeristy, USA

We develop and optimize a label-free in-droplet cell separation technology that could be broadly used in droplet microfluidics study. Dielectrophoresis properties of different types of cells are utilized to selectively concentrate the cell population within droplets. System efficiency was further evaluated using salmonella and macrophages.

12:15 - 12:45 **Invited Speaker**

W2A.005 UNLOCKING BIOMEDICAL DISCOVERIES THROUGH VOLUME PRODUCTION OF NANOPATTERNED MATERIALS

Neil Convery, John Stormonth-Darling, and **Nikolaj Gadegaard**
University of Glasgow, UK

Biomedical research relies on large datasets thus the need for large samples numbers and in many cases disposable devices demands manufacturing routes for cheap and fast sample production. Injection moulding meets those requirements where 100s of devices per hour can be manufactured. Where initial research focused on nanoscale replication, current interests are sparked around diagnostic devices with micron or sub-milimeter dimensions. Fueling this evolution is the advent of 3D printing where tooling quickly can be manufacturing without the need of specialized infrastructure.

Session W2B - Accelerometers and Gyros II

11:15 - 11:30

W2B.001 A MEMS GRAVIMETER QUALIFIED FOR EARTH TIDES MEASUREMENT

ShiHao Tang, HuaFeng Liu, ShiTao Yan, XiaoChao Xu, WenJie Wu, and LiangCheng Tu
Huazhong University of Science and Technology, CHINA

We develop a MEMS gravimeter that is sensitive and stable enough to observe earth tides. A nonlinear stiffness beam is employed to minimize the resonant frequency of the mass-spring system. The experiment data acquired by the MEMS gravimeter shows a good agreement with the theoretical earth tides, which indicates that the proposed MEMS gravimeter is qualified for earth tides measurement and is promising to be a very low-cost gravimeter.

11:30 - 11:45

W2B.002 A PIEZOELECTRIC RESONANT ACCELEROMETER FOR ABOVE 140DB LINEAR DYNAMIC RANGE HIGH-G APPLICATIONS

Seungyong Shin, Anosh D. Daruwalla, Minxiang Gong, Haoran Wen, and Farrokh Ayazi
Georgia Institute of Technology, USA

A frequency-output resonant accelerometer based on area-changing electrostatic softening effect is developed for ultra-high linear dynamic range (DR) applications. The accelerometer consists of a piezoelectrically-actuated resonator implemented in the device layer of an SOI wafer, and proof-mass in the handle layer, separated from the resonator by a sub-micron gap. Fabricated devices measure 850μg/rtHz VRW and 3mg BI with projected DR greater than 140dB for accelerations up to 50,000g.

11:45 - 12:00

W2B.003 GRATING-BASED ACCELERATION SENSORS WITH OPTICAL INTERFEROMETRIC READOUT AND CLOSED-LOOP CONTROL

Randall P. Williams[1], Neal A. Hall[1], and Brad D. Avenson[2]
[1]University of Texas, Austin, USA and [2]Silicon Audio, Inc., USA

We have developed an optically-read inertial sensor, which uses microfabricated diffraction gratings to sense the displacement of a macroscale proof mass. The measured noise floor of the sensor is 3 ng/√Hz from 0.1 Hz to 100 Hz, and a dynamic range of 176 dB is achieved using closed-loop feedback. Optical models were developed to explore the optical design space, resulting in innovate stepped grating designs which will facilitate optoelectronic integration for microscale devices.

12:00 - 12:15

W2B.004 EARTH TREMORS OBSERVATION BY A DIAMAGNETIC LEVITATION BASED INERTIAL SENSOR

Qiu Wang, Xiaofang Ren, Shitao Yan, Shimin Jiao, Xiaochao Xu, Xiaozhou Lei, Qiangwei Xu,
Chenyuan Hu, Zhilin Xu, Huafeng Liu, Pengshun Luo, and Liangcheng Tu
Huazhong University of Science and Technology, CHINA

We introduce a prototype of a diamagnetic levitating inertial sensor. This sensor includes a spring-mass system, which has a permanent magnet mass lifted by a fixed magnet for countering earth gravity and sandwiched by diamagnetic plates for constructing contactless suspension, and the sub-nm resolution optical interferometer for the mass displacement transducer. Due to the excellent sensitivity and low-frequency responses, earth tremors have been successfully observed by this sensor.

12:15 - 12:30

W2B.005 INTEGRATION OF A COMPLIANT THERMAL ACTUATOR FOR UNLATCHING IN A MEMS LATCH ACCELEROMETER

Murugappan Ramanathan and Rudra Pratap
Indian Institute of Science

We report the realization of a reusable MEMS g-Switch integrated with a compliant thermal actuator for delatching, using SOI wafer. The novelty here is in the tight integration of the delatching actuator that uses the same latching beams used as electrodes for threshold g-sensing, thus introducing minimal additional components.

12:30 - 12:45

W2B.006 AN ELECTROCHEMICAL MICROSEISMOMETER BASED ON A NEW ELECTROLYTE SYSTEM TO IMPROVE THE LOW-FREQUENCY PERFORMANCES

Bowen Liu, Junbo Wang, Deyong Chen, Jian Chen, Chao Xu, Wenjie Qi, Xichen Zheng, Hua Wei, and Guoqing Zhang
Chinese Academy of Sciences (CAS), CHINA

We proposed a new electrochemical microseismometer where the viscosity of the electrolyte solution was optimized by supplementation with glycerol. Compared to previously reported counterparts, the addition of glycerol increases the viscosity of the electrolyte solution, leading to 1) amplitude decreases at the middle-frequency domain and the extension of the working bandwidth; 2) decreases of convection noises and the corresponding decreases of the noise levels at the low-frequency domain.

Session W2C - RF MEMS II

11:15 - 11:45 **Invited Speaker**

W2C.001 3G – 4G – 5G: HOW BAW FILTER TECHNOLOGY ENABLES A CONNECTED WORLD

Robert Aigner and Gernot Fattinger
Qorvo Inc., USA

5G is highly anticipated by service providers, phone manufacturers and consumers. 5G marks a dramatic increase in data rates. The number of frequency bands requiring high performance filters increases significantly. BAW is particularly well suited for new bands below 6 GHz, many of which have very wide bandwidth and close-by neighbors. The only path forward to achieve full connectivity in LTE 4G + 5G wireless is RF integration; complexity of the antenna systems and the resulting coexistence challenges will dictate it. The article discusses trends for BAW, wide bandwidth and miniaturization.

11:45 - 12:00

W2C.003 AN ULTRA-HIGH-QUALITY FACTOR SILICON DISK RESONATOR

Guillermo Sobreviela, Xudong Zhou, Chun Zhao, Milind Pandit, and Ashwin A. Seshia
University of Cambridge, UK

A disk resonator demonstrates an ultra-high-quality factor (Q = 1e7) at room temperature. When embedded in a board-level feedback oscillator an excellent short-term stability (340 ppt @ 1s integration time) is measured. The use of a new higher-order bulk mode in the disk in combination with the anchor alignment with the nodal locations enables minimization of anchor losses, boosting the resonator quality factor.

12:00 - 12:15

W2C.004 A GENERIC TIN-C PROCESS FOR CMOS FEOL/BEOL-EMBEDDED VERTICALLY-COUPLED CAPACITIVE AND PIEZORESISTIVE RESONATORS

Chao-Yu Chen[1], Anurag A. Zope[1], Ming-Huang Li[2], and Sheng-Shian Li[1]
[1]National Tsing Hua University, TAIWAN and [2]University of Illinois Urbana-Champaign, USA

An improved titanium nitride composite (TiN-C) CMOS-MEMS platform for high resolution oscillating sensor applications is presented in this work that attempts to simultaneously validate the (i) vertically-coupled resonator (VCR) pair structure for increased linearity due to high mechanical stiffness coupler between VCR pair and (ii) embedded piezoresistive (PZR) transduction mechanism in a single chip for improved signal to noise ratio (SNR) due to high gauge factor of Poly-2 in CMOS process.

12:15 - 12:30

W2C.005 FDSOI ON LITHIUM NIOBATE USING Al_2O_3 WAFER-BONDING FOR ACOUSTOELECTRIC RF MICRODEVICES

Siddhartha Ghosh
Massachusetts Institute of Technology, USA

This work demonstrates amplification of surface acoustic waves in 128° Y-cut lithium niobate with thin film silicon as a semiconductor. A room temperature bonding process that utilizes Al_2O_3 as an intermediate layer has been developed and applied to the fabrication of acoustoelectric delay lines. Peak non-reciprocal contrasts of 11.2 dB/mm (normalized) and 9.8 dB (absolute) between forward and reverse traveling waves under the influence of applied dc bias are demonstrated at 460 MHz.

12:30 - 12:45

W2C.006 SUPER HIGH FREQUENCY LATERAL-FIELD-EXCITED ALUMINUM NITRIDE CROSS-SECTIONAL LAMÉ MODE RESONATORS

Guofeng Chen and Matteo Rinaldi
Northeastern University, USA

We report the first demonstration of super high frequency lateral-field-excited AlN cross-sectional Lamé mode resonators (CLMRs). Fabricated by a simple 2-mask process, LFE CLMRs operating at 4.2GHz show a high mechanical quality factor >1150 with a moderate electromechanical-coupling coefficient >1.2%. Such important features render AlN LFE CLMRs promising candidates for low-cost yet high-performance wireless communication technologies, such as LTE-Advanced contiguous carrier aggregation.

Session W2D - Tactile Sensors II

11:15 - 11:30

W2D.001 ELECTRONIC SKIN-INTEGRATED SOFT ROBOTIC HAND

Takafumi Yamaguchi, Takayuki Arie, Seiji Akita, and Kuniharu Takei
Osaka Prefecture University, JAPAN

In this study, we develop a tactile pressure sensor and a temperature sensor integrated with pneumatic soft robotic actuator. The important advance of this study is to integrate flexible sensors embedded in soft robotic structures without sacrificing softness and flexibility. As a proof-of-concept, real-time tactile force and temperature monitoring is successfully conducted. This development is an important step for the future robotic application as human-interactive electronics.

11:30 - 11:45

W2D.002 TACTILE SENSING FROM BACKSIDE OF FLEXIBLE PRINTED CIRCUIT USING LSI-INTEGRATED SENSOR WITH ELASTIC DOME STRUCTURE

Tatsuki Teranishi, Hideki Hirano, and Shuji Tanaka
Tohoku University, JAPAN

A new flip-chip mounting configuration of LSI monolithicintegrated tactile sensors on a flexible printed circuit (FPC) has been developed. The integrated sensor receives force from the backside of the FPC via an elastic dome structure. This configuration enables electrical connection between LSI and the FPC without through-LSI-via lines. Fragile sensing diaphragm is protected from external force by the dome. The total system was successfully demonstrated.

11:45 - 12:00

W2D.003 A FLEXIBLE TACTILE SENSOR TO DETECT STIFFNESS DISTRIBUTION WITHOUT MEASURING DISPLACEMENT

Tatsuho Nagatomo and Norihisa Miki
Keio University, JAPAN

We developed a flexible tactile sensor that scans the surface to detect the stiffness distribution. Note that the sensor does not need to know the displacement or strain of the target surface. Therefore, we propose a new stiffness sensor composed of four strain gauges with different Young's modulus to detect the target without measuring the strain. The developed flexible sensor uses encapsulated liquid metal as the electrodes and can scan the surface.

12:00 - 12:15

W2D.004 SELF-POWERED TRANSPARENT STRETCHABLE 3D MOTION SENSOR

Hang Guo, Xuexian Chen, Liming Miao, Haobin Wang, Ji Wan, and Haixia Zhang
Peking University, CHINA

We report a novel self-powered three-dimension motion sensor capable of independently detecting contact trajectory, pressure and velocity based on triboelectrification and electrostatic induction synchronously. Motion trajectories in the full plane can be identified by using a unique net-cross electrodes configuration design. The self-powered 3D motion sensor is a promising candidate in terms of human-computer interaction, anti-counterfeiting signatures, etc.

12:15 - 12:30

W2D.005 A BLOOD PRESSURE MONITORING DEVICE WITH TACTILE AND TENSION SENSORS ASSISTED BY MACHINE LEARNING TECHNIQUE

Kuan-Hua Huang, Fu Tan, Tzung-Dau Wang, and Yao-Joe Yang
National Taiwan University, TAIWAN

This work presents a continuous blood pressure monitoring system integrated with a highly sensitive pressure sensing array and a tension sensor. The sensing element consists of a conductive polymer with microdome structures and interdigital electrode pairs. The tension sensor was designed to ensure the operation conditions are optimal for acquiring stable signals. A machine learning algorithm was employed for estimating blood pressures from measured pulse wave signals.

12:30 - 12:45

W2D.006 TACTILE SENSING SYSTEM MODULE WITH MULTIPLE CMOS-MEMS INTEGRATED SENSORS ON 16 MBPS HIGH SPEED SHARED SERIAL BUS LINE

Chenzhong Shao[1], Hideki Hirano[1], Munetaka Nomoto[1], Hiroshi Miyaguchi[1], Takahiro Nakayama[2], Yoshiyuki Hata[3], Motohiro Fujiyoshi[3], Masanori Muroyama[1], and Shuji Tanaka[1]
[1]Tohoku University, JAPAN, [2]Toyota Motor Corporation, JAPAN, and [3]Toyota Central R&D Labs., Inc., JAPAN

We developed a PCB-based system module including 5 CMOS-MEMS integrated sensors for robot fingertip tactile sensing. The sensor used in the module has 3-axis force sensation with 2.7 mm square footprint, and 5 sensors are mounted on a shared serial bus with the high-dense pitch of 9 mm. We confirmed that these 5 integrated sensors operated simultaneously and correctly on the bus with high data rate up to 16 Mbps.

Session W2E - Optical Biosensors

11:15 - 11:30

W2E.001 RAPID PATHOGEN DETECTION AND ANTIMICROBIAL SUSCEPTIBILITY ASSESSMENT FROM URINE SAMPLES VIA AMPLIFICATION-FREE DETECTION OF RIBOSOMAL RNA OF SINGLE BACTERIA

Aniruddha M. Kaushik, Kuangwen Hsieh, Thomas DiSorbo, and Tza-Huei Wang
Johns Hopkins University, USA

We present a novel microfluidic platform for rapid detection and antimicrobial susceptibility assessment (AST) of bacteria directly from urine. We achieve rapid pathogen detection via probe hybridization to bacterial rRNA. Our assay is coupled with an integrated droplet platform capable of single-bacteria detection as well as rapid AST directly from urine samples. Our platform can detect the effect of antibiotics on bacterial growth after as little as 10-min. drug exposure.

11:30 - 11:45

W2E.002 CHIP-SCALE WHISPERING GALLERY MODE GLASS SHELL RESONATORS FOR CALORIMETRIC BIOSENSING APPLICATIONS

Vedant P. Sumaria, Sandeep Inampudi, and Srinivas Tadigadapa
Northeastern University, USA

We develop a novel biosensor consisting of a chip-scale whispering gallery mode resonators with High-Q factor and a micro-caloric system.We demonstrate a measurement resolution less than 10mK and a novel method of measuring temperature change to eliminate background noise that shows a great potential for detection of various biomolecules such as urea.

11:45 - 12:15 **Invited Speaker**

W2E.003 INTEGRATING MICROSYSTEMS WITH METAMATERIALS TOWARDS METADEVICES

Xiaoguang Zhao, Aobo Li, Guangwu Duan, Chunxu Chen, and **Xin Zhang**
Boston University, USA

Metamaterials, artificially engineered materials with extraordinary and controllable effective properties, have expedited the development of photonic and optical devices. Microsystems, or microelectromechanical systems (MEMS), provide powerful platforms to control the effective properties of metamaterials and integrate various functions into metamaterials. In this paper, we present the fundamentals of metamaterials, integration schemes of MEMS and metamaterials, and outlooks for metamaterial enabled photonic devices.

12:15 - 12:30

W2E.005 DETECTION OF AUTOANTIBODIES FOR TYPE 1 DIABETES USING LABEL-FREE OPTICAL SENSORS

Subin Mao, Silu Feng, and Long Que
Iowa State University, USA

Autoantibodies against pancreatic islet antigens are well established in Type 1 diabetes (T1D) panels. Detecting their levels is clinically diagnostic of T1D. We demonstrate the multiplexed detection of them using the label-free optical sensors. As low as 0.05 U/ml of three autoantibodies can be readily detect in serum, more sensitive than the available commercial ELISA kit.

12:30 - 12:45

W2E.006 DNA APTAMER-LINKED STRUCTURAL-COLOR HYDROGEL FOR REPEATABLE BIOCHEMICAL SENSING

Tomoki Hayashi[1], Masahiro Takinoue[2], and Hiroaki Onoe[1]
[1]Keio University, JAPAN and [2]Tokyo Institute of Technology, JAPAN

We proposed a DNA aptamer-linked structural-color hydrogel sensor that can quantitatively and repeatably detect biochemical substances through by visual information without any specific equipment. The hydrogel including colloidal crystal and DNA aptamer can convert the concentration of target substance to visible color change. And this gel can be initialized by heating. We believe that our biochemical sensor could be applied to various routine monitoring such as diagnosis, food and water safety.

12:45 - 14:30 **Lunch on Own**

13:30 - 14:30 **Industrial Stage Session 3 (Exhibit Hall)**

- 3a Helbling Technik Bern AG, SWITZERLAND
- 3b Polytec GmbH, GERMANY
- 3c Accurion GmbH, GERMANY
- 3d Lam Research Corporation, USA

14:30 - 16:30 **Poster Session W3P and Exhibit Inspection (refreshments will be served)**

Poster presentations are listed by topic category with their assigned number starting on page 42.

Session W4B - Accelerometers and Gyros III

16:30 - 16:45

W4B.001 A NOVEL NONLINEARITY REDUCTION METHOD IN DISK RESONATOR GYROSCOPES BASED ON THE VIBRATION AMPLIFIER EFFECT

Qingsong Li, Jiangkun Sun, Yi Xu, Peng Wang, Xin Zhou, Kuo Lu, Xuezhong Wu, and Dingbang Xiao
National University of Defense Technology, CHINA

We develop a method to reduce the nonlinearities in disk resonator gyroscopes (DRGs) by optimizing the positions of driving and sensing electrodes based on the vibration amplifier effect. A DRG with multi-layer driving electrodes are designed and effects of their positions on the DRG's nonlinearity are analyzed and tested. Results show that the oscillation amplitude and sensitivity of the DRG can be significantly increased while the ARW and bias instability can be significantly reduced.

16:45 - 17:00

W4B.002 SHAPE MEMORY FOIL-BASED ACTIVE MICRO DAMPING FOR PORTABLE APPLICATIONS

Kiran Jacob[1], Shahabeddin Ahmadi[2], Frank Wendler[2], Shuichi Miyazaki[3], and Manfred Kohl[1]
[1]Karlsruhe Institute of Technology (KIT), GERMANY, [2]Friedrich-Alexander-Universität Erlangen-Nürnberg, GERMANY, and [3]University of Tsukuba, JAPAN

Novel damping devices using micromachined shape memory foil actuators with position-based feedback are developed demonstrating damping capacities of up to 0.92, which compares favorably with the best viscoelastic damping concepts. The actuators consist of bridge, spiral and folded beam structures being compatible to MEMS batch fabrication technology. The operation meets the typical specifications of mobile devices subjected to human motion of a few Hz and high RMS acceleration up to 100 ms^{-2}.

17:00 - 17:15

W4B.003 AGC-LESS OPERATION OF HIGH-STABILITY LISSAJOUS FREQUENCY-MODULATED MEMS GYROSCOPES

Elia Bordiga, Marco Bestetti, and Giacomo Langfelder
Politecnico di Milano, ITALY

The paper presents the first FM gyroscope operated under Lissajous excitation without motion control. The method is compared to operation under velocity and displacement control to show that no difference in performance is achieved for the tested device. At the same time, the method can boost the performance in terms of low-power and low-noise by using single-transistor oscillators. Sub-0.3% linearity error, sub-100 ppm/k scale-factor stability and 6 mdps/√Hz noise are shown.

17:15 - 17:30

W4B.004 A BACKGROUND CALIBRATION TECHNIQUE FOR I/Q PHASE MISMATCH IN MEMS VIBRATORY GYROSCOPE

Yoshikazu Furuta[1], Ippei Takahashi[1], Nobuaki Matsudaira[1], Chao Chen[1], Takashi Katsuno[1] Tomohiro Nezuka[1], and Yong Ping Xu[2]
[1]DENSO Corporation, JAPAN and [2]National University of Singapore, SINGAPORE

This paper presents a background calibration technique for I/Q phase mismatch in MEMS vibratory gyroscope in order to improve Bias Instability (BI) without degrading Angle Random Walk (ARW). The gyroscope achieves ARW of 0.15 dph/√h and BI of 0.66 dph with the calibrated I/Q phase mismatch of +/-0.1 degree.

17:30 - 17:45

W4B.005 SMALL SIZE AND HIGHLY SENSITIVE DIFFERENTIAL MEMS ACCELEROMETER BASED ON DOUBLE-ENDED TUNING FORK RESONATORS

Eurico E. Moreira[1,2], Burkhard Kuhlmann[3], João Gaspar[2], and Luis A. Rocha[1,2]
[1]University of Minho, PORTUGAL, [2]International and Iberian Nanotechnology Laboratory (INL), PORTUGAL, and [3]Robert Bosch GmbH, GERMANY

A frequency modulated MEMS accelerometer encapsulated in vacuum is presented. The small size and the capability of encapsulation in vacuum are the main advantages reported. A high sensitivity for a single double-ended tuning fork resonator is achieved. Since a differential approach is implemented, the sensitivity is doubled. The structures were fabricated (commercial process) and characterized. The device sensitivity, temperature dependency and dynamic behavior were experimentally measured.

Session W4C - Cell/Bio Sensing

16:30 - 16:45

W4C.001 LEUKEMIA-ON-CHIP - ELECTRICAL IMPEDANCE SPECTROSCOPY AS AN ONLINE READOUT TO INVESTIGATE DRUG-CANCER INTERACTION

Furkan Gökçe, Paolo S. Ravaynia, Alicia J. Kaestli, Mario M. Modena, Andreas Hierlemann, and Kasper Renggli
ETH Zürich, SWITZERLAND

Based on recent advances in microphysiological systems, we established leukemia-on-chip to mimic blood cancer in vitro by continuously circulating leukemia cells in a microfluidic system. The platform is complemented by an integrated electrical impedance spectrometer (EIS), enabling to monitor the flowing cells in real-time. Preliminary results show that the platform can be used to investigate drug-cancer interaction online by EIS, promising higher-throughputs and label-free viability readout.

16:45 - 17:00

W4C.002 A COMBINED PROCESS OF SILICON SHADOW MASKING AND INKJET PRINTING (SSMP) FOR GRAPHENE OXIDE AND REDUCED GRAPHENE OXIDE MICROSTRUCTURES FOR SELECTIVE CELL CULTURING APPLICATIONS

Che-Hao Kang, Yu-Min Fu, Ching Chuan Kao, Jia-Wei Yang, Ming-Liang Tseng, Zih-Yu Yu, Yu-Ting Cheng, Guan-Yu Chen, Pu-Wei Wu, and Chung-Yu Wu
National Chiao Tung University, TAIWAN

This paper demonstrates a SSMP technqiue to fabricate a flexible cell culturing platform with reduced graphene oxide features on varieties of substrates, such as PDMS, SiO_2, Kapton, etc. Owing to the characteristics of low chemical usage, low process temperature and complexity, and high fault tolerance of inkjet printers, the process technique has shown its potential for biomedical applications.

17:00 - 17:15

W4C.003 NON-ENZYMATIC ELECTROCHEMICAL DETECTION OF GLUTAMATE USING TEMPLATED POLYMER-BASED TARGET RECEPTORS

Habib M.N. Ahmad, Bo Si, Gaurab Dutta, John R. Csoros, William Rudolph Seitz, and Edward Song
University of New Hampshire, USA

We propose a novel electrochemical biosensing platform for the detection of neurotransmitter glutamate using a polymer-based target receptors. This research demonstrates a non-enzymatic approach without the need of glutamate oxidase, leading to a more specific and rapid response. We demonstrate that the developed biosensor can achieve continuous and real-time detection of glutamate with high selectivity.

17:15 - 17:30

W4C.004 LABEL-FREE REAL-TIME IMAGING OF EXTRACELLULAR LACTATE FROM A HIPPOCAMPAL SLICE BASED ON CHARGE-TRANSFER-TYPE POTENTIOMETRIC REDOX SENSOR ARRAYS

Hideo Doi[1], Tomoko Horio[1], Eiji Shigetomi[2], Youichi Shinozaki[2], You-Na Lee[1], Tatsuya Yoshimi[1], Tatsuya Iwata[1], Toshihiko Noda[1], Kazuhiro Takahashi[1], Toshiaki Hattori[1], Schuichi Koizumi[2], and Kazuaki Sawada[1]
[1]Toyohashi University of Technology, JAPAN and [2]University of Yamanashi, JAPAN

A 128_128-pixel charge-transfer-type potentiometric redox sensor arrays with an enzyme functionalized membrane for biological measurement was studied, and they were applied to extracellular imaging of hippocampus. In the results of glutamate stimulation, lactate oxidase (LOX) and horseradish peroxidase (HRP) immobilized sensor was successfully label-free real-time imaging of extracellular lactate from hippocampal slice.

17:30 - 17:45

W4C.005 RAPID PURIFICATION, ENRICHMENT, AND DETECTION OF BIOMOLECULES USING BULK ACOUSTIC WAVE RESONATORS

Weiwei Cui[1], Luye Mu[2], Wei Pang[1], Mark Reed[2], and Xuexin Duan[1]
[1]Tianjin University, CHINA and [2]Yale University, USA

We report an acoustic-microfluidic method that enables rapid concentration and accurate detection of biomolecules in blood samples. We demonstrate that this method, that we call Nanoparticle-assisted Acoustic Molecular Concentration (NAMC), has been proven to realize a concentration factor exceeding two orders magnitude within 30 s. We then integrate the NAMC with an ELISA principle and develop a no-wash cancer biomarker detection technique with a detection limit as low as 0.05 ng/mL.

17:45 - 18:00

W4C.006 DUAL-FUNCTION INTRAVASCULAR CATHETER FOR ATHEROSCLEROSIS DIAGNOSTICS

Yuan Luo[1], Parinaz Abiri[2], Rene R.S. Packard[2], Tzung K. Hsiai[2], and Yu-Chong Tai[1]
[1]California Institute of Technology, USA and [2]University of California, Los Angeles, USA

We present a novel intravascular catheter, with dual-functions of electrical impedance spectroscopy(EIS) and flow fraction reserve(FFR), validated in pigs for atherosclerosis diagnostic. FFR has been the standard tool for plaque vulnerability yet could produce false negative. EIS has been demonstrated to distinguish the lipid-rich pool, the signifying feature of rupture-prone plaques. The performance of these two functionalities can significantly enhance diagnostics accuracy for atherosclerosis.

Session W4D - IR Detectors

16:30 - 16:45

W4D.001 INFRARED DETECTOR USING ORGANIC NANO-PILLAR ARRAYS

Yoshiharu Ajiki[1], Tetsuo Kan[2], Masayuki Yahiro[3], Akiko Hamada[3], Junji Adachi[3], and Chihaya Adachi[3]
[1]Olympus Corporation, JAPAN, [2]University of Electro-Communications, JAPAN, and [3]Kyushu University, JAPAN

A near infrared photo-detector (NIR-PD) using self-assembled organic crystalline arrays has been reported. Since such structure was found tohave an activation energy as large as 0.41 eV, Mid to Near- Infrared light can be detected. In this paper, we report that an IR-PD based on acombination of organic crystal material and plasmonic nano-pillar structures could detect over 2.0-μm-long IR light, which cannot be detected by using metal/Si Schottky diodes.

16:45 - 17:00

W4D.002 INFRARED PHOTODETECTOR WITH COPPER RESONATOR IN SILICON NANOHOLE ARRAY

Shun Yasunaga[1], Tetsuo Kan[2], Hidetoshi Takahashi[1], Tomoyuki Takahata[1], and Isao Shimoyama[1]
[1]University of Tokyo, JAPAN and [2]University of Electro-Communications, JAPAN

We present a silicon-based infrared photodetector furnished with an array of a nano-scale copper plate which induces localized surface plasmon resonance (LSPR). Each plate is placed at the bottom of a sidewall. The copper resonators and backside-illuminating configuration efficiently generated photocurrent with vertical NIR irradiation.

17:00 - 17:15

W4D.003 THRESHOLD-TRIGGERED MEMS-CMOS INFRARED RESONANT DETECTOR WITH NEAR-ZERO STANDBY POWER CONSUMPTION

Sila Deniz Calisgan, Sungho Kang, Vageeswar Rajaram, Zhenyun Qian, and Matteo Rinaldi
Northeastern University, USA

This paper demonstrates an integrated microsystem that can turn itself ON to quantify the intensity of infrared radiation when an above-threshold signature is present, otherwise remain dormant with near-zero standby power consumption. The proposed sensor combines the unique advantage of two recently developed technologies, the zero-power nature of micromechanical photoswitches and the high resolution of aluminum nitride MEMS resonant infrared detectors with integrated spectral selectivity.

17:15 - 17:30

W4D.004 MICROMACHINED UNCOOLED $Si_XGe_YO_{1-X-Y}$ MICROBOLOMETER INTEGRATED METASURFACE FOR UNCOOLED INFRARED DETECTION

Amjed Abdullah[1], Akshay Koppula[1], Omar Alkorjia[1], Cameron Warder[1], Tao Liu[2], Edward Kinzel[2], and Mahmoud Almasri[1]
[1]University of Missouri, USA and [2]Missouri University of Science and Technology, USA

This paper presents a detailed study of metasurface integrated uncooled infrared (IR) microbolometers for long wavelength detection. The inclusion of the metasurface permits engineering the IR absorptance with respect to wavelength, polarization, and angle-of-incidence. Measured results for fabricated devices show that the inclusion of the metasurface improved the 1/f-noise by two orders of magnitude over an identical device with no metasurface.

17:30 - 17:45

W4D.005 NANOPLASMONICS ENHANCED BROADBAND ULTRA-SENSITIVE MID-IR SENSOR ARRAY INTEGRATED WITH MICROFLUIDICS

Zhihao Ren, Jingxuan Wei, Dihan Hasan, Bowei Dong, Guangya Zhou and Chengkuo Lee
National University of Singapore, SINGAPORE

This paper shows a broadband ultra-sensitive IR sensor with novel folded gold nanoantenna sensing array on CaF2 substrate integrated with microfluidic channel, which will allow, for the first time, continuous monitoring wide-band finger print IR absorption of liquid and solution using enhancement of plasmonic nanoantenna. The broadband detection window is over 10 times larger than nanorod antenna, which pave the way to real-time fingerprint monitoring and various molecular recognition.

17:45 - 18:00

W4D.006 3-D THERMAL RADIATION SENSORS ON OPTICAL FIBER TIPS FABRICATED USING ULTRASHORT LASER PULSES

Jonathan W. Smith[1], Joe S. Suelzer[2], Nicholas G. Usechak[2], Vincent P. Tondiglia[2], and Hengky Chandrahalim[1]
[1]US Air Force Institute of Technology, USA and [2]Air Force Research Laboratory, USA

This work demonstrates 3-D heat radiation sensors which were fabricated using ultra-short laser pulses on optical fiber tips. The released sensor showed linear response over the temperature range of 20-120ºC; temperature sensitivity of ~50 pm/ºC at around 1550 nm wavelength; and sensitivity improvement of better than 900% compared to the unreleased sensors.

Session W4E - Mixed Session

16:30 - 17:00 **Invited Speaker**

W4E.001 HIGH PERFORMANCE PIEZOELECTRIC AlN MEMS RESONATORS FOR LIQUID SENSING AND BEYOND – THE POTENTIAL OF PIEZOMEMS

Ulrich Schmid and Michael Schneider
Vienna University of Technology, AUSTRIA

Piezoelectric MEMS resonators based on advanced aluminium nitride thin films are a promising and versatile technology platform to tackle a multitude of sensory challenges. In this talk, we will give an overview on recent achievements in this field focusing on potential applications for e.g. sensing the viscosity and density of liquids and serving as integrated transducers to push the performance of buckled membranes.

17:00 - 17:15

W4E.003 ALN PIEZOELECTRIC MICROMACHINED ULTRASONIC TRANSDUCER ARRAY MONOLITHICALLY FABRICATED ON TOP OF PRE-PROCESSED CMOS SUBSTRATES

Eyglis Ledesma[1], Ivan Zamora[1], Francesc Torres[1], Arantxa Uranga[1], Vassil Tzanov[1], Nuria Barniol[1], Eloi Marigo[2] and Mohan Soundara-Pandian[2]
[1]Electronics Eng. Dept, Universitat Autonoma de Barcelona, SPAIN and [2]Silterra Malaysia Sdn. Bhd, MALAYSIA

A 6x6 AlN PMUTs array with competitive performance as actuator and as sensor compared with other devices using the AlN as piezoelectric material is presented. The novelty is that the AlN-PMUT is fabricated over pre-processed CMOS wafers allowing compactness, better signal processing and higher fill factor (not limited by wafer bonding) than reported. One row of the array achieves acoustic sensitivities as actuator of 130 Pa·mm·V-1 and sensor of 5.9 V/MPa in fluorinert with a fill factor of 54%.

17:15 - 17:30

W4E.004 A PIEZORESISTIVE MEMS BAROMETER WITH THERMOMECANICAL STRESS REJECTION

Enri Duqi, Lorenzo Baldo, Mikel Azpeitia Urquia, and Giorgio Allegato
ST Microelectronics, ITALY

We model and develop a single-wafer stress rejection method to reduce soldering and bending effects on sensors output. The method is demonstrated on a barometer with on-chip spring suspended active area. By moving the package complexity inside the MEMS die, the proposed structure, applicable to other sensors (e.g. humidity, accelerometers), enables cost-effective fully-molded packaging.

17:30 - 17:45

W4E.005 NOVEL HINGE MECHANISM FOR VACUUM TRANSDUCTION HIGH PERFORMANCE CAPACITIVE MEMS MICROPHONES

Samer Dagher[1,2], Carine Ladner[1], Stéphane Durand[2], and Loic Joet[1]
[1]University of Grenoble, Aples CEA-Leti, FRANCE and [2]LAUM UMR-CNRS, FRANCE

Design, fabrication and first experimental results of a microscale hinge mechanism allowing the mechanical transfer of a force between two atmospheres. Applied to the design of a capacitive MEMS microphone, this mechanism divides the device into two separate parts: a pressure harvesting membrane in air, linked to a capacitive transducer sitting in vacuum. Theoretically this separation should increase overall microphone performance (SNR>75dB(A)) while maintaining a small device footprint (<2mm2).

18:00 **Adjourn for the Day**

19:00 - 22:00 **Transducers/EUROSENSORS Conference Banquet**

Thursday, 27 June

08:00 **Continental Breakfast in Exhibit Hall**

08:30 - 09:15 **Plenary Presentation IV - EUROSENSORS 2018 Fellow**

Th1A.P04 DIAMOND: A NEW CHEMICAL SENSOR'S BEST FRIEND?

Emmanuel Scorsone
CEA-LIST, FRANCE

Diamond materials in different forms, including single crystal, polycrystalline, or nanoparticles, feature a number of very attractive physical/chemical properties for the development of both chemical or biochemical sensors. In the last decade considerable work has been carried out to process diamond (seeding, etching, patterning, controlling surface chemistry, etc.) so that it has now become a serious candidate material for implementation in advanced sensor technologies. Here we report on some of the work achieved by our team in this area, focusing more particularly on sensors used for the detection of small organic compounds both in the liquid phase or gas phase.

09:15 - 09:30 **EUROSENSORS 2019 Fellow Announcement**

09:30 - 09:45 **Transition**

Session Th1A - Flexible Substrate Sensors

09:45 - 10:00

Th1A.001 A PRINTED FLEXIBLE SENSOR BASED SILK-FIBROIN FOR DISTINGUISHING THE EXISTING STATES OF WATER: LIQUID OR GASEOUS?

Danliang Wen, Xin Liu, Haitao Deng, Deheng Sun, and Xiaosheng Zhang
University of Electronic Science and Technology of China, CHINA

We proposed a flexible humidity sensor based on silk fibroin which can distinguish liquid and gaseous states of water molecules, owning to the unique feature of selective absorption of silk fibroin to water molecules. A printing process of conductive patterns on polymeric substrate is successfully developed, which endows the device with remarkable precision and flexibility. In addition, as an attractive application potential, it is demonstrated to accurately discriminate the breathing states.

10:00 - 10:15

Th1A.002 INTEGRATING METAMATERIAL AND MICROCHANNEL ONTO FLEXIBLE PAPER AS MINIATURIZED BIOCHEMICAL SENSING PLATFORM

Hong Zhou[1], Cheng Yang[2], Donglin Hu[1], Dongxiao Li[1], Xindan Hui[1], Yongjie Yi[1], and Xiaojing Mu[1]
[1]Chongqing University, CHINA and [2]Third Military Medical University, CHINA

We design and fabricate a flexible miniaturized biochemical sensing platform for quantitative, rapid and label-free detection of glucose molecule by integrating the low-cost paper compatible metamaterial and a structure-design-flexible microchannel onto the paper. The result shows that the limit of detection (LOD) and sensitivity of the sensor reach 0.52 mmol/L and 10.15 MHz/(mmol/L), respectively, lower than the glucose level in normal human.

10:15 - 10:30

Th1A.003 TWO-DIMENSIONAL TUNGSTEN DISELENIDES INTEGRATED ON PAPER SUBSTRATE FOR HIGHLY FLEXIBLE AND SENSITIVE GAS SENSOR

Woo Sung Lee and Jungwook Choi
Yeungnam University, KOREA

This paper reports a highly sensitive gas sensor based on 2D tungsten diselenide nanolayers on cellulose paper. The fabrication process is simple, rapid, and cost-effective, and the sensor shows a high mechanical flexibility and a sensing response toward NO_2 exposure.

10:30 - 10:45

Th1A.004 DIGITAL MICROFABRICATION ON PAPER AND CLOTH FOR HEAVY METAL DETECTION AND REMEDIATION

Arshya Bamshad and Hyoung Jin Cho
University of Central Florida, USA

This study introduces a novel and rapid digital fabrication technique for transferring metals on flexible substrates such as cloth, paper, and thermo-resistant films, and demonstrates a low-cost method for prototyping and producing micro/nano flexible sensors and devices. A set of office equipment was used for this technique. The applications have been demonstrated for the detection and remediation of heavy metal contaminants in water with devices made on paper and cloth, respectively.

Session Th1B - Water Sensors

09:45 - 10:00

Th1B.001 A NOVEL FLEXIBLE MICROWAVE SENSOR CHIP FOR SIMULTANEOUS MONITORING OF OIL ACIDITY AND WATER CONTENT

Xiecheng Tang[1,2], Qiannan Xue[1], Haitao Liu[2], and Xuexin Duan[1]
[1]Tianjin University, CHINA and [2]Civil Aviation University of China, CHINA

This paper presents a square spiral-based flexible microwave sensor chip fabricated by MEMS technology. It can realize monitoring of oil acidity and water content at the same time with only a few millimeters size and can be bend suitable for various tubing wall shapes. The results showed an excellent discriminating ability on water content and acid value without interference from acidity or water in oil.

10:00 - 10:15

Th1B.002 DESIGN OF CHEMICAL SENSOR COATINGS BASED ON BLENDS OF A SINGLE POLYMER-PLASTICIZER PAIR FOR DETECTION OF SINGLE OR MULTI-ANALYTE AQUEOUS SOLUTIONS

Nicholas Post[1], Kartick Sothivelr[1], Florian Bender[1], Fabien Josse[1], Antonio Ricco[2], and Edwin Yaz[1]
[1]Marquette University, USA and [2]Stanford University, USA

New, adaptable chemical sensor coatings using a single polymer-plasticizer pair have been designed for detection of single or multiple chemical compounds in aqueous solutions. By modifying blend mixing ratios, sensing characteristics of coatings are varied, allowing for extraction of multiple sensing parameters. Experimental data indicates high selectivity, permitting unique single analyte identification. Estimation theory-based signal processing also allows for accurate multi-analyte detection.

10:15 - 10:30

Th1B.003 DRAGONFLY-LIKE MICRO SAMPLING DEVICE FOR EXTRACTING NANO-LITER SAMPLE FROM PLANTS

Panpan Gao[1], Toshihiro Kasama[1], Maia Godonoga[1], Yoshishige Endo[1], Tetsushi Koide[2], Atsushi Ogawa[3], and Ryo Miyake[1]
[1]University of Tokyo, JAPAN, [2]Hiroshima University, JAPAN, and [3]Akita Prefectural University, JAPAN

We design and fabricate a micro sampling device which shows potential to continuously and low-invasively extract quantitative sample (around 50 nL) from plants. By analyzing the sample with suitable analyzer, plants' nutrient demand can be better understood which makes fertilizing plants based on their demand possible. To test the performance of our sampling device, we applied our device to extract sample from one kind of Japanese spinach and final results proved the feasibility of our idea.

10:30 - 10:45

Th1B.004 SMART BIOSENSOR FOR RAPID AND SIMULTANEOUS DETECTION OF WATERBORNE PATHOGENS IN TAP WATER

Sura A. Muhsin[1], Muthana Al-Amidie[1], Zahar Mlaji[1], Zhenyu Shen[1], Amjed Abdullah[1], Jiayu Liu[1], Ferris Dweik[1], Ibrahem Jasim[1], Majed El-Dweik[2], Shuping Zhang[1], and Mahmoud Almasri[1]
[1]University of Missouri, USA and [2]Lincoln University, USA

This paper presents a new design of a MEMS based impedance biosensor for simultaneous detection of multiple waterborne pathogens in tap water . The testing panel includes Legionella, E. coli O157: H7 and Salmonella. The device is unique in terms of its ability to focus, concentrate low amount of pathogens to a detectable level, and detect them using interdigitated electrode (IDE).

Session Th1C - RF MEMS III

09:45 - 10:00

Th1C.001 A PLANAR SINGLE-ACTUATOR BI-STABLE SWITCH BASED ON LATCH-LOCK MECHNISM

Yang Gao[1], Toshiki Ema[2], Zeyuan Cao[3], Sheng Ni[1], Elena Y.L. Chan[1], Osamu Tabata[2], Toshiyuki Tsuchiya[2], Xiaohong Wang[3], and Man Wong[1]
[1]Hong Kong University of Science and Technology, HONG KONG, [2]Kyoto Univeristy, JAPAN, and [3]Tsinghua University, CHINA

Described presently is a micro-fabricated planar bi-stable mechanical switch driven using only one compliant electro-thermal actuator. The state-defining bi-stable mechanism is connected to the actuator via a displacement. More robust state-locking is achieved using a latch-lock rather than the commonly employed buckled-mode mechanism. Realized on a silicon-on-insulator substrate, the device could be switched between the "set" and "reset" states robustly.

10:00 - 10:15

Th1C.002 PARALLEL LOGICS USING MULTIMODE EXCITATION OF A SINGLE MEMS RESONATOR

Nizar Jaber[1,2], Saad Ilyas[2], and Mohammad Younis[2]
[1]Purdue University, USA and [2]King Abdullah University of Science and Technology (KAUST), SAUDI ARABIA

We present a resonator that executes multiple logic gates in parallel. The concept is based on simultaneously encoding the binary information at different modes of vibration of a microplate. The method allows the device to perform as a fully integrated logic gate and as a parallel logic processor where the same device can perform multiple logic gates simultaneously which decreases the device footprint and reduces the power consumption required to perform multiple Boolean functions.

10:15 - 10:30

Th1C.003 MECHANICALLY MODULATED MICROWAVE CIRCULATOR

Mustafa Mert Torunbalci[1], Suresh Sridaran[2], Richard C. Ruby[2], and Sunil A. Bhave[1]
[1]Purdue University, USA and [2]Broadcom Ltd., USA

This work presents a differential FBAR circulator that uses the bending mode to mechanically modulate the FBAR mode without any varactors or switches.

10:30 - 10:45

Th1C.004 SWITCHABLE MECHANICAL RESONANCE INDUCED BY HYSTERETIC PIEZOELECTRICITY IN FERROELECTRIC CAPACITORS

Yanbo He[1], Bichoy Bahr[2], Mengwei Si[1], Peide Ye[1], and Dana Weinstein[1]
[1]Purdue University, USA and [2]Texas Instruments, USA

This paper reports on the ferroelectric hysteretic behavior of RF MEMS resonators fabricated in TI's PZT-based FeRAM CMOS technology. A solid-state elastic waveguide is formed with a periodic array of Ferroelectric Capacitors (FeCAPs) to form a confined 722MHz acoustic mode. Frequency response under uniform and alternating poling is investigated, showing a bias-dependent pole-zero transition in both amplitude and phase at the FeCAP coercive voltage.

Session Th1D - Image Sensing

09:45 - 10:00

Th1D.001 A NOVEL MICROFLUIDIC PLATFORM FOR LABEL-FREE 3D IMAGING OF BIOLOGICAL CELLS

Rahul Singh Kotesa[1], Saransh Arora[2], G.K. Ananthasuresh[1], and Prosenjit Sen[1]
[1]Indian Institute of Science, INDIA and [2]Birla Institute of Technology and Science, Pilani, INDIA

We report a novel microfluidic platform for label-free 3D imaging of cellular and intracellular components of biological cell. The device uses two opposing air-liquid interfaces integrated inside a microchannel. When the cells approach the air-liquid interfaces, they rotate along the direction of flow. The rotation of the cell was recorded using a high-speed camera. Cell and nucleus boundary were mapped using image processing and 3D reconstruction was done using the point cloud.

10:00 - 10:15

Th1D.002 HIGH-COLOR-PURITY MICROFLUIDIC QUANTUM DOTS LIGHT-EMITTING DIODES USING THE ELECTROLUMINESCENCE OF THE LIQUID ORGANIC SEMICONDUCTOR BACKLIGHT

Masahiro Kawamura[1], Hiroyuki Kuwae[1], Takumi Kamibayashi[1], Juro Oshima[2], Takashi Kasahara[3], Shuichi Shoji[1], and Jun Mizuno[4]
[1]Waseda University, JAPAN, [2]Nissan Chemical Corporation, JAPAN, [3]Hosei University, JAPAN, and [4]Research Organization for Nano and Life Innovation, JAPAN

We proposed microfluidic quantum dots light-emitting diodes (QLEDs) using a liquid organic semiconductor (LOS) and quantum dots (QDs) solutions for high-color-purity flexible display. The proposed all liquid-based QLEDs realize ultimate flexible devices. LOS and QDs solutions were used as a backlight and a luminophore, respectively. Compared with conventional organic light-emitting diodes (OLEDs), high-color-purity with narrow full width at half maximum (29.8 nm) was archived.

10:15 - 10:30

Th1D.003 LIGHT DRIVING OF ON-CHIP MICRO-GEL ACTUATOR TOWARDS MASSIVE INTEGRATION

Yuha Koike[1], Yoshiyuki Yokoyama[2], and Takeshi Hayakawa[1]
[1]Chuo University, JAPAN and [2]Toyama Industrial Technology Research and Development Center, JAPAN

We propose driving method of on-chip gel actuator by using light irradiation. The proposed driving method enables local heating of temperature responsive gel actuator. Therefore, the proposed method realizes massive integration of gel actuators on a chip. This driving method and massive integrated gel actuators will contribute to high-throughput and high-efficient microfluidic chip applied for single cell manipulations.

10:30 - 10:45

Th1D.004 HYDROGEN ION MICROSCOPE USING 2 μM PITCH PH IMAGE SENSOR AND ANALYSIS OF MOUSE HIPPOCAMPAL SLICE

Chinatsu Kawakami[1], You-Na Lee[1], Hideo Doi[1], Tomoko Horio[1], Yasuyuki Kimura[1], Eiji Shigetomi[2], Youichi Shinozaki[2], Toshihiko Noda[1], Tatsuya Iwata[1], Kazuhiro Takahashi[1], Schuichi Koizumi[2], and Kazuaki Sawada[1]
[1]Toyohashi University of Technology, JAPAN and [2]University of Yamanashi, JAPAN

We have developed a novel pH image sensor with a fine pixel pitch that is shorter than one-tenth of 23.55 μm of previous one. The pixel pitch of 2 μm is small enough to observe the cell action of a single cell. By using this sensor, we could observe the different tendency of proton diffusion in each region of hippo-campus. Additionally, we confirmed that the sensor clearly captured the distribution of neural cell response.

10:45 - 11:15 **Break and Exhibit Inspection**

Session Th2A - Cell on a Chip II

11:15 - 11:30

Th2A.001 IN VITRO DEVELOPMENT OF THE EMBRYO IN A MICROFLUIDIC DEVICE FOR AUTOMATIC EMBRYO TRAPPING AND CO-CULTURE WITH ENDOMETRIAL CELLS

Shalaka Bhosale[1], Mushou Chen[2] and Cheng-Hsien Liu[1]
[1]National Tsing Hua University, TAIWAN and [2]Chang Gung Medical Foundation, TAIWAN

The micro device in this study integrates the functions of automatically trapping embryos, co-culturing with 3T3cells and collecting medium from each embryo respectively. The overall results show that embryos can develop faster in the proposed bio-chip than using traditional IVF method.

11:30- 11:45

Th2A.002 ON-CHIP PRE-TREATMENT OF BIOLOGICAL SAMPLES FOR THE ISOLATION OF ADIPOSE STEM CELLS (ASCs)

Marion Valette[1,2,3], Mathias Bouguelmouna[3], Mélanie Mariotte[1,5], Rémi Courson[1], Marie-Charline Blatché[1], Amandine Girousse[4], Coralie Sengenès[4], Karine Reybier[2,3], and Anne-Marie Gué[1,3]
[1]LAAS-CNRS, FRANCE, [2]PharmadeV, FRANCE, [3]Université Toulouse III Paul Sabatier, FRANCE, and [4]Stromalab, FRANCE and [5]Univeristy of Limoges, FRANCE

Adipose Stem Cells (ASCs), cells of considerable interest for regenerative medicine, are present in adipose tissue and circulate in lymph. Currently, no method exists to prove that they circulate in blood. We propose an original 2-steps Lab-on-chip which aims at isolating ASCs from complex biological samples. Here, we present the first step, based on hydrodynamic filtration, which pre-isolates ASCs by removing cells with a diameter below 10µm (red blood cells, lymphocytes, etc).

11:45 - 12:00

Th2A.003 AN INTEGRATED DEVICE FOR MONITORING SINGLE CELL METABOLISM

Bocheng Yu, Yuting Wu, Peng Yu, Dong Huang, and Zihong Li
Peking University, CHINA

We model, fabricate a microelectrode based single cell oxygen consumption rate monitoring device, which features cell capture structure, high spatial resolution and multichannel real-time sensing. The device is fabricated with planar microfabrication techniques, therefore has the advantage of low-cost and mass production. Electrodes applied oxygen permeable membrane to enhance the sensitivity. Single cell metabolism was monitored after adding drugs.

12:00 - 12:15

Th2A.004 ASPIRATION AND MASS MEASUREMENT OF MICROPARTICLES AND UNICELLULAR ORGANISMS VIA MICROPIPETTE RESONATORS

Juhee Ko[1], Donghyuk Lee[2], Bong Jae Lee[1], Taewook Kang[3], Sangkeun Kauh[4], and Jungchul Lee[1]
[1]Korea Advanced Institute of Science and Technology (KAIST), KOREA, [2]Samsung Electronics, KOREA, [3]Sogang University, KOREA, and [4]Seoul National University, KOREA

This paper reports the first mass measurement of specific microparticles and unicellular organism out of a group on a petri dish by using micropipette resonators with an open end. The micropipette is fabricated by a customized pipette puller with a galvano mirror which widens the effective heating region thus makes a pulled pipette with a relatively long region of uniform cross-section. The pulled pipette is integrated with an optical pickup unit (OPU) for real-time frequency readout.

12:15 - 12:30

Th2A.005 ECM-BASED STRETCHABLE MICROFLUIDIC SYSTEM FOR IN VITRO 3D TISSUE CULTURE

Azusa Shimizu[1], Wei Huang Goh[2], Michinao Hashimoto[2], Shigenori Miura[3], and Hiroaki Onoe[1]
[1]Keio University, JAPAN, [2]Singapore University of Technology and Design, SINGAPORE, and [3]University of Tokyo, JAPAN

We present an extracellular matrix (ECM)-based stretchable microfluidic system for in vitro 3D tissue culture, mimicking in vivo blood vessels. The target cells can be cultured with perfusion and stretch simultaneously in our proposed system. Our ECM (collagen)-based microfluidic device was fabricated by dissolving water-soluble sacrificial molds fabricated with 3D printer. We demonstrated perfusion and stretch of collagen microfluidic devices with culturing HUVECs.

12:30 - 12:45

Th2A.006 STUDIES OF NEUROSPHERES CULTURED USING ADULT HIPPOCAMPAL PROGENITOR CELLS UNDER OFF-CHIP MAGNETIC STIMULATION

Renyuan Yang, Emily Kozik, Bhavika Patel, David Jiles, Donald Sakaguchi, and Long Que
Iowa State University, USA

Transcranial magnetic stimulation (TMS) is being used as a clinical treatment for several neurological disorders. But the exact mechanisms for magnetic stimulation (MS) are still unclear. Adult hippocampal progenitor cells (AHPCs) are cultured as neurospheres (NSs) in microwell chips or petri dishes, which is an ideal model for studying neurodegenerative diseases. The study of the effects of MS on AHPC NSs is reported for the first time.

Session Th2B - Gas Sensors

11:15 - 11:45 **Invited Speaker**

Th2B.001 SMART ENVIRONMENTAL SENSOR SYSTEMS FOR A DIGITAL AND SUSTAINABLE WORLD

Markus Graf

Sensirion Automotive Solutions AG, SWITZERLAND

The world´s progressing digitalization has generated a wave of omnipresent megatrends such as Industry 4.0, Internet of Things and Artificial Intelligence. Many of the related innovations are driven by sophisticated functionalities, which become only possible by recent progress in sensor miniaturization. Indeed, miniaturized sensors are essential for accessing and collecting data of the environmental context, thus enabling undreamt applications. First, the concept of smart sensor systems and the "sensing-star" model for describing their key characteristics are introduced. Second, it is discussed, how in this holistic approach the systems design is influenced and embedded in the context.

11:45 - 12:00

Th2B.003 RESISTANCE-TYPE HUMIDITY SENSOR USING CNTS SENSING MATERIAL WITH Al_2O_3 CONFORMAL COATING FOR ENHANCED SENSITIVITY

Chien-Ya Hung[1], Wei-Lun Sung[2], Sih-Chieh Chen[3], and Weileun Fang[1]

[1]National Tsing Hua University, TAIWAN, [2]imec TW, TAIWAN, and

[3]Industrial Technology Research Institute, TAIWAN

This study presents a resistance-type humidity sensor using carbon nanotubes (CNTs) with Al_2O_3 coating. $Al_2O_3$is the excellent material for moisture absorption. Thus, this study used the serpentine CNTs design integrated with Al_2O_3 conformal coating by atom-layer deposition (ALD) process to form a CNTs/ Al_2O_3composite for enhanced sensitivity of device. Measurements show the sensitivity of sensors with 300°C annealed CNTs/ Al_2O_3composite is ~7-fold higher than that of bare-CNTs.

12:00 - 12:15

Th2B.004 FLEXIBLE GAS SENSOR ARRAY BASED ON MATRIX OF MOLECULARLY IMPRINTED MATERIALS AND FULL PRINTING PROCESS

Lingpu Ge, Fumihiro Sassa, and Kenshi Hayashi

Kyushu University, JAPAN

This paper proposes a flexible gas sensor array system fabricated by full printing process; The production of sensors using a low-cost, large-scale, high-speed printing technology. Realizing the production of multiple sensors in a small area. Detection of a variety of gases using the sensor array. The results show that it is possible to make a full-printing gas sensor by adjusting the solvent of acetylene carbon black and molecularly imprinted polymer; 36 sensors are produced on a 3cm*3cm paper.

12:15 - 12:30

Th2B.005 A SENSITIVE RESONANT GAS SENSOR BASED ON MULTIMODE EXCITATION OF A BUCKLED BEAM

Amal Hajja[1], Nizar Jaber[1,2], Nouha Alcheikh[1], and Mohammad I. Younis[1]

[1]King Abdullah University of Science and Technology (KAUST), SAUDI ARABIA and [2]Purdue University

We report an ultra-sensitive gas sensor based on tracking the frequency shift in the first two lowest frequencies of a heated bridge resonator. By operating near buckling, we show significant frequency shifts in the first mode as high as 200% compared to less than 0.5% resistance changes. Also, by monitoring the shift in the frequency of the second mode, we demonstrate the potential to achieve selectivity for certain applications.

12:30 - 12:45

Th2B.006 A LIGHT-ACTIVATED MICROPOWER GAS SENSOR FOR THE DETECTION OF NO_2 DOWN TO THE PARTS PER BILLION (PPB) RANGE

Olga Casals[1], Nicolai Markiewicz[1,2], Cristian Fabrega[1], Isabel Gracia[3], Carles Cane[3], Hutomo Suryo Wasisto[2], Andreas Waag[2], and J. Daniel Prades[1]

[1]Universitat de Barcelona, SPAIN, [2]Technical University of Braunschweig, GERMANY, and

[3]IMB-CNM CSIC, SPAIN

We present an NO_2 gas sensor operating in the part per billion range (ppb) with microwatt (μW) power consumption. These are the best figures reported to date in conductometric metal-oxides (MOX) sensors operated with light (instead of heat) at room temperature. We achieved these remarkable figures miniaturizing the devices in a novel monolithic-integrated configuration, so-called "micro-light-plate".

Session Th2C - Energy & Power MEMS II

11:15 - 11:30

Th2C.001 HIGH MASS-LOADING AND MECHANICAL STRENGTH SUPERCAPACITOR BY GRAPHENE/CARBON FIBER COMPOSITES

Yuanyuan Huang[1,2], Caiwei Shen[1,3], Zirong Tang[2], Sunxiang Zheng[1], Tielin Shi[2], and Liwei Lin[1]

[1]University of California, Berkeley, USA, [2]Huazhong University, CHINA and

[3]University of Massachussets Dartmouth, USA

We presents a high mass-loading and mechanical strength supercapacitor by reduced graphene oxide/carbon fiber (RGO/CF) composite electrodes to achieve high mass-loading level for practical wearable and flexible energy storage applications. The interconnected CFs work as the framework for enhanced mechanical strength. The complex 3D hierarchical structure maintain high efficient ion transport for high mass-loading electrodes independent of the thickness of the electrode up to 4 mg cm-2.

11:30 - 11:45

Th2C.002 A NOVEL ANODE IN HIGH-PERFORMANCE LITHIUM-ION BATTERY BASED ON ADVANCED NANOMATERIALS AND NANOFABRICATION TECHNOLOGY

Bingmeng Hu, Xinyan Jia, and Xiaohong Wang
Tsinghua University, CHINA

We report an anode with silicon nanoparticles (SiNPs) enclosed in 3D cross-linked network of Ti3C2Tx, which can encapsulate SiNPs as well as provide void space for the expansion of SiNPs during lithiation. Moreover, the intrinsically high electron conductivity of MXene provides conductive channels to improve the electrode dynamics and greatly enhanced the cycle performance of lithium-ion battery. The nanostructure is formed by vacuum filtration and pyrolysis for the first time.

11:45 - 12:15 **Invited Speaker**

Th2C.003 PIEZOELECTRIC PZT THIN FILMS: DEPOSITION, EVALUATION AND THEIR APPLICATIONS

Isaku Kanno
Kobe University, JAPAN

Piezoelectric thin films have attracted attention as key materials of next generation functional micro-devices. The characteristic features of piezoelectric MEMS, especially focusing on the deposition of the PZT thin films, and the evaluation of piezoelectric thin films will be presented from the viewpoint of design and fabrication of piezoelectric MEMS devices.

12:15 - 12:30

Th2C.005 INTEGRATED FABRICATION OF SERIALLY-CONNECTED HIGH VOLTAGE MICROBATTERIES VIA MULTILAYER ELECTRODEPOSITION

Michael Synodis, James Pikul, Sue Ann Bidstrup Allen, and Mark Allen
University of Pennsylvania, USA

We report a scheme for the integrated fabrication of MEMS-scale, serially connected battery cells. The approach exploits multilayer electrodeposition of active and sacrificial layers to generate structures that can be formed into high voltage power sources. Batteries manufactured using this technique offer the potential to match supply voltages to system needs, ranging from conventional electronics to direct drive of high voltage electrostatic or piezoelectric MEMS.

12:30 - 12:45

Th2C.006 MEMS MASS FLOW CONTROLLER FOR LIQUID FUEL SUPPLY TO HCCI-DRIVEN ENGINE

Michael Schiffer[1], Piotr Mackowiak[1], Ha-Duong Ngo[1,2], Oswin Ehrmann[1], Martin Schneider-Ramelow[1], and Klaus-Dieter Lang[1]
[1]Fraunhofer IZM, GERMANY and [2]Hochschule für Technik und Wirtschaft Berlin, GERMANY

A MEMS mass flow controller for liquid fuel delivery to a miniaturized homogeneous charge compression ignition (HCCI) engine is presented with highly improved on-/off-characteristic (3300:1) and fuel delivery range. Various fuels were calibrated, for instance, a diethyl ether/oil mixture can be dis-pensed with a maximum mass flow rate of 12 g/min (at 100 kPa inlet pressure). A power consumption of 50 µW during continuous operation was measured.

Session Th2D - Microfluidic II

11:15 - 11:30

Th2D.001 NANOPARTICLE CAPTURE USING ULTRASONIC ACTUATION

Ruhollah Habibi and Adrian Neild
Monash University, AUSTRALIA

A novel method of capturing nanoparticles in a microfluidic channel is characterized in terms of capture efficiency under a range of conditions.

11:30 - 11:45

Th2D.002 ON-CHIP CAVITATION GENERATION BASED ON ULTRA-HIGH-SPEED FLOW CONTROL

Yusuke Kasai, Shinya Sakuma, and Fumihito Arai
Nagoya University, JAPAN

We propose on-chip cavitation generation system based on ultra-high-speed flow control. Remarkably, we succeeded in the on-chip cavitation generation only by flow control and observing it on a microscope. In addition, we found that the result corresponded to the FEM analysis which showed that the cavitation occurred at the area where the dynamic pressure was below the saturated vaper pressure.

11:45 - 12:00

Th2D.003 MICROFABRICATED AIR-MICROFLUIDICS VIRTUAL IMPACTOR WITH GROOVE-BASED ENVELOPE-FLOW PARTICLE FOCUSING SYSTEM

Omid Mahdavipour, Dorsa Fahimi and Igor Paprotny
University of Illinois, Chicago, USA

We present the design, modeling, fabrication and experimental results of an inertial particle size-separator called a virtual impactor (VI), combined with a novel groove-based envelope-flow particulate matter (PM) focusing system. This air-microfluidic circuit demonstrates improved collection efficiency, i.e. selectivity to a target size of airborne particulates. This microfluidic systems presents an important improvement in the functionality of air-microfluidic MEMS PM sensors.

12:00 - 12:15

Th2D.004 ESTABLISHMENT OF TREATMENT OF RETINAL VEIN OCCLUSION BY PHYSICAL STIMULI OF ELECTRICALLY-INDUCED BUBBLES

Mei Sumimoto[1], Daisuke Matsumura[1], Keita Ichikawa[1], Keiko Miwa[1], Hideyasu Oh[2], Yasuhiro Moriizumi[3], and Yoko Yamanishi[1]

[1]Kyushu University, JAPAN, [2]Hyogo Prefectural Amagasaki General Medical Center, JAPAN, and [3]BEX co., Ltd, JAPAN

This paper reports a novel treatment for retinal vein occlusion by minimally invasive physical stimuli of electrically-induced bubbles when they collapse. The invasiveness is closely link to the distance between the device and blood vessel, and which was electrically discriminated. We evaluated our device using vascular vessels of chick embryos whose dimeter is about 100μm, and retinal veins of pig, as in vitro and in vivo model.

12:15 - 12:30

Th2D.005 MAXIMUM PRESSURE CAUSED BY DROPLET IMPACT IS DEPENDENT ON THE DROPLET SIZE

Thanh-Vinh Nguyen[1] and Isao Shimoyama[2]

[1]National Institute of Advanced Industrial Science and Technology (AIST), JAPAN and [2]Toyama Prefecture University, JAPAN

We show that the maximum pressure pmax on the contact area of a droplet impacting on a rigid substrate increases with droplet size. Using MEMS-based force sensors, we were able to directly measure pmax, which occurred at the very beginning stage of the impact. We also confirmed the dependence of impact induced pressure on the droplet size by measuring the critical impact velocity that causes the liquid penetration through a mesh for droplets with different sizes

12:30 - 12:45

Th2D.006 A NOVEL WEARABLE SWEAT RATE SENSOR FOR BOTH DOMINANT AND RECESSIVE SWEAT RATE MEASUREMENT

Kunpeng Gao, Xiaolin Wang, Bin Yang, Xiang Chen, Xiuyan Li and Jingquan Liu

Shanghai Jiao Tong University, CHINA

We developed a novel wearable sensor for measuring sweat rate conveniently. In this design, sweat was absorbed by super hydrophilic material coated microporous PDMS. By the help of super hydrophilic coating, sweat could evaporated naturally and quickly. The sweat sensor could detect dominant and recessive sweating.

12:45 - 13:15 **Award Ceremony and Closing Remarks**

13:15 **Conference Adjourns**

Poster Presentations

M3P – Monday, 24 June (14:30 – 16:30) **T3P** – Tuesday, 25 June (14:30 – 16:30)
W3P – Wednesday, 26 June (14:30 – 16:30)

Poster Categories

Acoustic Microdevices and RF MEMS
Bio-Sensors and Bio-Microsystems
Chemical and Environmental Sensors and Microsystems
Energy and Power MEMS
Integrated Photonics and Optical MEMS
Materials, Fabrication, and Packaging Technologies
Mechanical/Physical Sensors and Microsystems
Medical Microsystems
Microfluidics (Non-Bio)
Nanoscale Devices and Nanomaterials
Transducers with Soft, Flexible or Composite Materials

Monday - Acoustic Microdevices and RF MEMS

14:30 - 16:30

M3P.001 A MICRO-RESONATOR BASED DIGITAL TO ANALOG CONVERTER FOR ULTRA-LOW POWER APPLICATIONS

Sally Ahmed, Xuecui Zou, and Hossein Fariborzi
King Abdullah University of Science and Technology (KAUST), SAUDI ARABIA

We present a micro-resonator based digital to analog converter (DAC) for the internet of things and low power applications. The device consists of a fixed-fixed beam with multiple electrodes. The air-gap between each electrode and the beam is varied based on the weight of input bits. The tested DAC consumes a few pico-joules/conversion step with a sampling rate of 226 S/s. Device down-scaling can reduce the energy consumption and increase the sampling rate by 2-3 orders of magnitude.

M3P.002 ALN PMUT WITH CROSSED-CAVITY FOR BETTER ACOUSTIC PRESSURE OUTPUTS IN LIQUID AT HIGH FREQUENCY

Eyglis Ledesma[1], Vassil Tzanov[1], Iván Zamora[1], Francesc Torres[1], Arantxa Uranga[1], Núria Barniol[1], Eloi Marigó[2], and Mohan Soundara-Pandian[2]
[1]Universitat Autònoma de Barcelona, SPAIN and [2]Silterra Malaysia Sdn. Bhd., MALAYSIA

A novel AlN PMUT compatible with CMOS-MEMS process is presented. The design is a squared membrane with 4 different sections. The operational frequency of the device in liquid is in the 10 MHz range. Our FEM model shows that the cross-slit increases the displacement as well as the acoustic pressure outputs by a factor of 10. The resulted 4 PMUT sections are sealed by a passive Si3N4 layer allowing reliable liquid operation as demonstrated by the experimental acoustic characterization.

M3P.003 APPLICATION OF MEMS ENABLED EXCITATION AND DETECTION SCHEMES TO PHOTOACOUSTIC IMAGING

Jonas Kusch, Gordon M.H. Flockhart, Ralf Bauer, and Deepak Uttamchandani
University of Strathclyde, UK

We integrate arrays of thin-film AlN piezoelectric micromachined ultrasonic transducers into our photoacoustic sensing system. The pulsed laser source is miniaturised using a high repetition rate custom MEMS Q-switched Nd:YAG laser. Finally, we use this system for imaging of synthetic targets in biological matrices.

M3P.004 DEVELOPMENT OF MECHANICALLY-ROBUST PIEZOELECTRIC MICROMACHINED ULTRASONIC TRANSDUCER (PMUT) WITH ISLAND-SHAPED PZT MONOCRYSTALLINE THIN FILM

Pham N. Thao, Shinya Yoshida, and Shuji Tanaka
Tohoku University, JAPAN

We developed a mechanically-robust piezoelectric micromachined ultrasonic transducer (pMUT) based on a Pb(Zr,Ti)O3 monocrystalline thin film (Mono-PZT). This material has an excellent figure of merit for pMUT. However, its brittleness easily leads to the fractures of conventional design during operation. Here, an island-shaped Mono-PZT structure covered with ring-shaped polyimide thin film was proposed and significantly improved the mechanical reliability of pMUT under the dynamic fracture test.

M3P.005 FULL-SYSTEM SIMULATION OF AIRBORNE CAPACITIVE MEMS TRANSDUCERS OPERATING IN THE AUDIBLE AND ULTRASONIC REGIME

Gabriele Bosetti[1], Johannes Manz[2], Ulrich Krumbein[2], and Gabriele Schrag[1]
[1]Technical University of Munich, GERMANY and [2]Infineon Technologies AG, GERMANY

A compact model of an airborne capacitive acoustic MEMS transducer is generalized to perform predictive full-system simulations in the audible and ultrasonic regime. The model helps to assess and understand the interaction between the device and the surrounding air for frequencies up to 100 kHz. The very good agreement between simulations and measurements highlights the predictive power of the model and its potential for full-system design and optimization.

M3P.006 PIEZOELECTRIC MICROMACHINED ULTRASONIC TRANSDUCERS WITH CORRUGATED DIAPHRAGMS USING SURFACE MICROMACHINING

Guo-Lun Luo and David A. Horsley
University of California, Davis, USA

We present a study of corrugated diaphragm PMUTs which have up to 3.2X higher volume velocity than conventional PMUTs of the same area. The PMUTs are manufactured by a surface-micromachining process forming a high fill-factor (80%) array, and corrugations can be added without any additional masks or process steps. The PMUTs with corrugations are implemented to have increased displacement, and the corrugations are formed by the same fabrication step along with release holes.

M3P.007 RESEARCH OF A MINIATURIZED BROADBAND MEMS PHASE DETECTOR AND ITS TEMPERATURE EFFECT FOR APPLICATION IN PHASE-LOCKED LOOPS

Juzheng Han and Rushan Chen
Nanjing University of Science and Technology, CHINA

We presents the miniaturization of a broadband MEMS phase detector at X-band and a new phase-locked loop system based on it. Remarkable size-reduction and broadband property is verified. Temperature effect of the phase detector is studied. An integrated PLL circuit model is established to validity its application potential.

M3P.008 ULTRA LOW ACOUSTIC LOSS BUTTERFLY LAMB WAVE RESONATOR

Jie Zou[1,2], Anming Gao[3], and Albert P. Pisano[2,4]
[1]Lambwave LLC, USA, [2]University of California, Berkeley, USA, [3]University of Illinois, Urbana-Champaign, USA and [4]University of California, San Diego, USA

This study reports a novel butterfly AlN Lamb wave resonator (LWR) with ultra low acoustic loss indicated by the measured anti-resonance quality factor (Qa) as high as 4,021. While the Qr is dominated by the resistance which is poor without the thick metal re-wiring and probing pad in academia, the Qa is a good indicator of the actual acoustic loss level instead and is usually close to Qmax of Bode Q-curve in the IDT-excited devices.

Tuesday - Acoustic Microdevices and RF MEMS

T3P.001 A BISTABLE ULTRASONIC MEMS DEVICE WITH AN INTEGRATED PIEZOELECTRIC SCANDIUM-ALN THIN FILM ACTUATOR FOR SWITCHING

Manuel Dorfmeister, Michael Schneider, and Ulrich Schmid
Vienna University of Technology, AUSTRIA

This work reports on a novel concept for switching between the two stable states of compressively pre-stressed bistable MEMS membranes using integrated piezoelectric scandium aluminium nitride thin film actuators. With this design we are able to measure the bistable switching with a Laser Doppler Vibrometer and show the switching mode and the FFT characteristics which show extremely high accelerations and are a promising concept for high sound pressure levels for ultrasonic applications.

T3P.002 A PIEZOELECTRIC MEMS LOUD SPEAKER BASED ON CERAMIC PZT

Haoran Wang[1], Mengyuan Li[2], Yuanyuan Yu[1], Zhenfang Chen[3], Yingtao Ding[2], Huabei Jiang[4], and Huikai Xie[1, 2]
[1]University of Florida, USA, [2]Beijing Institute of Technology, CHINA, [3]MEMS Engineering and Materials Inc., USA, and [4]University of South Florida, USA

We develop a piezoelectric MEMS loud speaker. By using bonding and carefully tuned chemical mechanical polishing process, the speaker is made of ceramic PZT that is only about 5 um thick. The high sound pressure level generated by the speaker under a small driving voltage is comparable with those of commercial speakers or microspeaker arrays with similar size.

T3P.003 ALN PMUT-BASED ULTRASONIC POWER TRANSFER LINKS FOR IMPLANTABLE ELECTRONICS

Bernard Herrera, Flavius Pop, Cristian Cassella, and Matteo Rinaldi
Northeastern University, USA

We report on the first demonstration of acoustic power transfer through the use of Aluminum Nitride (AlN) Piezoelectric Micro Machined Ultrasonic Transducer (PMUT) arrays at transmission distances suitable for intra-body powering applications. An output power of ~1 µW, from a minute (8 mm x 8 mm x 300 µm) PMUT array chip, was achieved on an optimal 330Ω load. The operating frequency was 2 MHz, through a distance of 4 cm, in an oil medium resembling intra-body conditions.

T3P.004 BROADBAND ACOUSTICAL MEMS TRANSCEIVERS FOR SIMULTANEOUS RANGE FINDING AND MICROPHONE APPLICATIONS

Sebastian Anzinger[1,2], Christian Bretthauer[2], Johannes Manz[2], Ulrich Krumbein[2], and Alfons Dehé[1,3]
[1]University of Freiburg, GERMANY, [2]Infineon Technologies AG, GERMANY, and [3]Hahn-Schickard, GERMANY

We present a capacitive dual-backplate MEMS transducer, allowing a combined use as ultrasonic transceiver and audio microphone. Requiring below 10V bias and using miniaturized housings with dimension of 4x3x1 mm_, the proposed system allows an integration into space and power critical systems like e.g. smartphones. The analog ASIC allows a broadband reception of acoustic signals in both audio and ultrasonic frequency range. An audio microphone performance of 68 dB(A) SNR is reached.

T3P.005 DISTRIBUTED MULTICONTACT RF MEMS SWITCH FOR POWER HANDLING CAPABILITY IMPROVEMENT

Yulong Zhang, Zhuhao Gong, Huiliang Liu, and Zewen Liu
Tsinghua University, CHINA

We design, model, fabricate, and test an RF MEMS switch with distributed contacts, which is compared with the conventional parallel contacts switch. To illustrate the uneven current distribution among these different contacts, a current uniformity factor is proposed. The CoventorWare and HFSS are used to simulate the proposed switch. The simulated and tested results show that the distributed contacts are beneficial for power handling capability improvement.

T3P.006 OFF-RESONANCE DYNAMICS BEHAVIOR OF PIEZOELECTRIC MICROMACHINED ULTRASONIC TRANSDUCER

Xinxin Liu, Xuying Chen, Dengfei Yang, Xianhao Le, Lei Yang, and Jin Xie
Zhejiang University, CHINA

Off-resonance behavior of ultrasonic transducer commonly exists in nonlinear application and Doppler measurement. In this work, we studied the off-resonance dynamics of the piezoelectric micro-machined ultrasonic transducer theoretically with experimental measurements, demonstrating that the pulse-echo mode off-resonance dynamic can be used to measure frequency shift.

T3P.007 PZT MICROMACHINED PIEZOELECTRIC ULTRASONIC TRANSDUCERS WITH GOOD COUPLING TO SOLIDS

Tingting Yang, Yijia Du, Zhanqiang Xing, Weiliang Ji, Yu Chen, Xiangyu Sun, Dongdong Gong, and Lifang Liu
China Academy of Engineering Physics, CHINA

This paper presents PZT thick film based piezoelectric micromachined ultrasonic transducer (PMUT), showing good coupling capability to solids. Thickness-measuring ability through 5 cm thick graphite was evaluated with a 1MHz PMUT array as transmitter providing 8 Vpp input, and another single PMUT of identical frequency response as receiver showing 0.2 Vpp (after 20 times magnification) output.

T3P.008 SIGNAL ENHANCEMENT IN MEM RESONANT SENSORS USING PARAMETRIC SUPPRESSION

James M.L. Miller, Nicholas E. Bousse, Dongsuk D. Shin, Hyun-Keun Kwon, and Thomas W. Kenny
Stanford University, USA

We use parametric suppression to enhance the signal of a phase-modulated microelectromechanical charge detector more than ten-fold. While previous reports use parametric enhancement to amplify signals in amplitude-modulated resonant sensors, our technique relies on the increase in phase slope that accompanies parametric suppression to enhance the signal in a phase-modulated sensor.

T3P.009 ULTRA-SENSITIVE AND BROAD RANGE PHONONIC-FLUIDIC CAVITY SENSOR FOR DETERMINATION OF MASS FRACTIONS IN AQUEOUS SOLUTIONS

Frieder Lucklum and Michael J. Vellekoop
University of Bremen, GERMANY

This paper presents a 3D-printed phononic-fluidic cavity sensor to measure volumetric physical properties of a liquid. Novel aspects include: new type of acoustic fluid sensor with very high, linear sensitivity in a very broad concentration range; solid-air 3D phononic crystals confining a fluidic cavity resonator to generate strong, well separated cavity resonance within phononic band gap; and ultra-sensitive determination of sodium chloride and glucose concentrations in aqueous solutions.

Wednesday - Acoustic Microdevices and RF MEMS

W3P.001 A FULLY DIFFERENTIAL THIN FILM PIEZO ON SILICON FLEXURAL MODE RING RESONATOR WITH EXCEPTIONAL QUALITY FACTOR

Gayathri Pillai, Mei-Feng Lai, and Sheng-Shian Li
National Tsing Hua University, TAIWAN

We report an innovative four-segmented electrode design of a ring-based flexural mode Thin Film Piezo on Substrate resonator exhibiting the highest loaded Quality factor (Ql) among its flexural mode counterparts working in the MHz range. The device has a resonance frequency of 5.25 MHz and features a Ql of 628 and 6,696 in air and vacuum respectively for a driving power of 0dBm. In vacuum, the device exhibits a Phase Noise of -108 dBc/Hz at 1 kHz offset for a 10 kHz loop BW.

W3P.002 ACOUSTIC MICRO-OPTO-MECHANICAL TRANSDUCERS FOR CRACK WIDTH MEASUREMENT ON CONCRETE STRUCTURES FROM AERIAL ROBOTS

Diego Marini[1], Luca Belsito[1], Luca Masini[1], Miguel A. Trujillo[2], Ángel L. Petrus[2], Daniel Martìnez[2], Francisco Gamero[2], José M. Barrientos[2], Elena Blanco[2], and Alberto Roncaglia[1]
[1]Institute for Microelectronics and Microsystems (IMM-CNR), ITALY and [2]FADA-CATEC, SPAIN

A novel Micro-Opto-Mechanical acoustic sensor that can be utilized to measure the width of surface opening cracks in concrete structures from aerial robots is presented. The sensor is used in combination with a piezoelectric emitter operating at 54 kHz in a crack width measurement procedure that provides a resolution around 0.2 mm. The method is tolerant to pressure variations during contact with concrete, which may easily occur when operating the sensors from aerial robots.

W3P.003 ANALYSIS OF ALUMINUM NITRIDE RESONATORS AND FILTERS OVER TEMPERATURE AND UNDER HIGH POWER

Arash Fouladi Azarnaminy and Raafat R. Mansour
University of Waterloo, CANADA

Our paper presents an experimental investigation of the performance of Aluminum Nitride (AlN) on silicon resonators operating over a wide temperature range. The resonators are measured over the temperature range of -196C to +120C. Linear and nonlinear characterization of the proposed resonator is presented over an input power from 8dBm to 20dBm. The paper also presents measured results of a 3-pole band-pass filter designed using such type of resonators.

W3P.004 CHIP SCALE MICRO-ACOUSTIC RADIO FREQUENCY GYRATOR

Yao Yu and Matteo Rinaldi
Northeastern University, USA

This paper reports on the first demonstration of a micro-acoustic radio frequency (RF) gyrator. The purposed circuit architecture is fully passive, with two micro-acoustic filters being periodically modulated by RF switches to achieve the non-reciprocity.

W3P.005 FLY-INSPIRED MEMS DIRECTIONAL ACOUSTIC SENSOR FOR SOUND SOURCE DIRECTION

Ashiqur Rahaman and Byungki Kim
Korea University of Technology & Education, KOREA

A novel approach of sound source detection is developed and experimentally demonstrated by two Ormia ochracea's ear inspired piezoelectric MEMS directional microphones which is easier than the conventional approaches based on time difference of arrival (TDOA). To feasible low noise application areas, the sensing is fabricated by using a unique combination made of aluminium nitride and D33 mode. Besides sensing, the microphone is designed in circular shaped to enhance the frequency response.

W3P.006 PHASE NOISE MEASUREMENTS OF ALUMINUM SCANDIUM NITRIDE OSCILLATORS

Andrea Lozzi[1], Marco Liffredo[1], Ernest Ting-Ta Yen[2], Jeronimo Segovia-Fernandez[2], and Luis Guillermo Villanueva[1]
[1]École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND and [2]Texas Instruments, USA

This paper reports the first study on phase noise (PN) of oscillators based on aluminum scandium (17%) nitride contour mode resonators (CMR). We use RF probes to contact the resonator in the oscillator, allowing fast measurements over a large number of resonator. PN decreases as the resonator Q increases. The oscillator built on the highest Q=1400 resonator reaches -99 dBc/Hz at 1 kHz offset frequency. This is 10 dB better compared to an oscillator using an aluminum nitride CMR with identical Q.

W3P.007 QUALITY FACTOR ENHANCEMENT OF ALN-ON-SI LAMB WAVE RESONATORS USING A HYBRID OF PHONONIC CRYSTAL SHAPES IN ANCHORING BOUNDARIES

Muhammad W.U. Siddiqi and Joshua E.-Y. Lee
City University of Hong Kong, HONG KONG

This paper describes the novel use of a hybrid phononic crystal array formed by two PnC shapes on anchoring boundaries of a 7th harmonic Lamb wave resonator. We demonstrate the effect of the hybrid PnC in boosting Q to the order 10^4. The hybrid PnC array comprises a disk PnC with a wide bandgap and a ring PnC as an intermediary routing layer for I/O electrical feeds to more effectively reduce anchor loss. We show that the disk PnC provides 47dB of acoustic attenuation in Lamb wave delay line.

W3P.008 THE IMPACT OF BOTTOM ELECTRODE COVERAGE RATE ON ELECTROMECHANICAL COUPLING AND QUALITY FACTOR OF ALN MEMS CONTOUR MODE RESONATOR

Soon In Jung[1], Gianluca Piazza[2], and Hoe Joon Kim[1]
[1]Daegu Gyeongbuk Institute of Science and Technology (DGIST), KOREA and [2]Carnegie Mellon University, USA

We present experimental studies to analyze the impact of bottom electrode design on electromechanical properties of AlN contour mode resonators. 220 MHz and 1 GHz resonators with various bottom electrode coverage rates are studied and the results clearly show that the electrode design impacts both quality factor and electromechanical coupling coefficient of the device. Our results indicate that a proper design of the bottom electrode could further improve the current state of AlN resonators.

M3P.009 A BUBBLE-FREE AND LOW-SHEAR-STRESS MICROFLUIDIC DEVICE FOR HIGH-QUALITY MONITORING OF ZEBRAFISH EMBRYONIC DEVELOPMENT

Zhen Zhu[1], Yangye Geng[1], Zhangyi Yuan[1], Siqi Ren[1], Meijing Liu[2], Zhaozheng Meng[3], and Dejing Pan[4]
[1]Southeast University, CHINA, [2]Nanjing University, CHINA, [3]ETH Zurich, SWITZERLAND, and [4]Soochow University, CHINA

We present a microfluidic device that enables the capture and culture of zebrafish embryos and the real-time monitoring of dynamic embryonic development. This rapid-prototyping, low-cost and easy-to-operate microfluidic device offers a promising platform for the long-term culturing of immobilized zebrafish embryos under continuous medium perfusion and the high-quality screening of the developmental dynamics.

M3P.010 A LAB-ON-A-CHIP FOR THE EXTRACTION OF BACTERIAL NUCLEIC ACIDS FROM WHOLE HUMAN BLOOD

Matthias Hügle[1], Lara S. Siegel[1], Ole Behrmann[2], Frank T. Hufert[2], Gregory Dame[2], and Gerald A. Urban[1]
[1]University of Freiburg, GERMANY and [2]Brandenburg Medical School Theodor Fontane, GERMANY

We present a Lab-on-a-Chip system for the extraction of bacterial nucleic acids from whole human blood. Compared to classical methods, with extraction times between hours and days, the used chip can lyse the cells and extract their nucleic acids within three minutes. The extraction is based on the concept of the gel electrophoresis.

M3P.011 A PORTABLE MICROFLUIDIC SYSTEM FOR THE DETECTION OF HEALTH BIOMARKERS IN GRAPES AT THE POINT OF NEED

Eduardo J.S. Brás, Rui M.R. Pinto, Ana M. Fortes, Virginia Chu, Pedro Fernandes, and João P. Conde
Universidade de Lisboa, PORTUGAL

In this work, a portable microfluidic system for the detection of a plant health marker (Azelaic Acid, AzA) is presented. The system optically detects AzA by monitoring the kinetic behavior of the enzyme Tyrosinase, which is immobilized on microbeads trapped in a microchannel. The fluidic system is coupled with custom built thin-film silicon photosensors for signal transduction. It is demonstrated that it is possible to distinguish healthy from infected vines by monitoring the AzA content.

M3P.012 APTAMER-BASED ALLERGEN SENSING SYSTEM FOR FOOD SAFETY

Hamza Abdelli, Takashiro Tsukamoto, Takahiro Ito, Kumi Y. Inoue, Tomokazu Matsue, and Shuji Tanaka
Tohoku University, JAPAN

We developed a portable aptamer based allergen sensing system for food safety. A complete device with illumination and luminescence observation optical system, signal processor, power management system and data transmitter was fabricated. The luminescence distribution from the sensing sheet could be successfully distinguished by the developed system.

M3P.013 DETECTION OF UREA AND AMMONIA WITH ALUMINIUM COATED POLYSILICON NANORESONATORS

Fidal Vallam Thodi, Chinnamani Mottour Vinayagam, Gayathri S., Anju Chadha, and Enakshi Bhattacharya
Indian Institute of Technology, INDIA

Aluminium coated polysilicon nanoresonator has been used to design a urea biosensor. The etching characteristic of Al by the ammonium from urea/urease reaction was used for quantification. Al film was deposited by e-beam evaporation on 165 nm thin polysilicon beam nanoresonator, followed by urease immobilization on its surface. The biosensor was found to be highly sensitive and specific and can have potential application in the field of medical diagnostics and environmental monitoring.

M3P.014 DEVELOPMENT OF WRINKLED 3D SKIN-EQUIVALENT BY CYCLIC UNIAXIAL STRETCHABLE SKIN-ON-A-CHIP

Ho Yeong Kim, Kyunghee Kim, Hye Mi Jeon, and Gun Yong Sung
Hallym University, KOREA

We applied a method that allowed human fibroblasts and keratinocytes to be perfused with media to form 3D skin equivalents that were then uniaxially 10%-stretched for 12 h per day (at either 0.01 or 0.05 Hz) for up to 7 days to form wrinkled skin-on-a-chip (WSOC). These results suggest that WSOCs can be used to examine skin aging and as an in vitro tool to evaluate the efficacy of anti-wrinkle cosmetics and medicines.

M3P.015 DYNAMIC IN VITRO BIOSENSING WITH FLEXIBLE MICROPOROUS MULTIMODAL CELL-INTERFACIAL SENSORS

Ashley Chapin, Pradeep Rajasekaran, Jens Herberholz, William Bentley, and Reza Ghodssi
University of Maryland, USA

We demonstrate cell-interfacial electrochemical electrodes, fabricated on a porous cell culture membrane, for direct continuous monitoring of cell molecular release profiles with high local concentrations and time resolution. Dynamic, concentration-dependent detection of serotonin (5-HT) was demonstrated, mimicking cell release. Simultaneous measurements of 5-HT and physical cell coverage further demonstrate the potential to correlate multiple factors along pathways in tissue and organ models.

M3P.016 HIGH THROUGHPUT CELL MECHANOPHENOTYPING VIA MICROFLUIDIC CONSTRICTIONS WITH MULTIPLEXED ELECTRICAL SENSORS

Norh Asmare, A K M Arifuzzman, Ningquan Wang, Mert Boya, Ruxiu Liu, and A. Fatih Sarioglu
Georgia Institute of Technology, USA

The work presented herein shows a microfluidic cytometry platform that uses constrictive channels monitored with a multiplexed electrical sensing network to measure cell mechanical properties. The parallel microfluidic architecture combined with code division multiplexed electrical sensing of cells enable throughput levels that otherwise are not possible in constriction transit time measurement based devices.

M3P.017 IMPEDANCE-ENABLED CATHETER-BASED REAL-TIME HEMATOCRIT SENSOR

Ryan C. McNaughton[1], Reza Ghaffarivardavagh[1], Huseyin Seren[1], Xiaoguang Zhao[1], Stephan W. Anderson[2], and Xin Zhang[1]
[1]Boston University, USA and [2]Boston University Medical Center, USA

We integrate impedance analysis with a conventional peripheral intravenous catheter for the purpose of continuous, real-time hematocrit sensing as a measure of hemorrhage detection in trauma patients. Modeling, fabrication, and experimental validation of coiled electrodes along the catheter surface demonstrates an ability to perceive alterations in the near field medium corresponding to changing hematocrit.

M3P.018 INTEGRATED ON-CHIP ISOLATION AND ANALYSIS OF EXOSOME TUMOR MARKERS VIA MICROFLUIDIC SYSTEM

Yunxing Lu, Zule Cheng, Kun Wang, Youlan Qu, Yanan Bai, Shihui Qiu, Jianlong Zhao, and Hongju Mao
Chinese Academy of Sciences (CAS), CHINA

Here we develop, test and optimize an exosome detection system which integrates exosome isolation and tumor marker analysis on a single chip. Compared to traditional exosome detection methods, our distinctive chip design enables on-chip exosome incubation and labeling and achieves the low-interference fluorescence detection through queued microbeads in our novel micropillar array. This system has proved its potential in clinical application.

M3P.019 MEASUREMENT OF DIELECTRIC PROPERTIES OF MICROALGAE WITH DIFFERENT LIPID CONTENT USING ELECTROROTATION AND NEGATIVE DIELECTROPHORESIS

Song-I Han, Can Huang, and Arum Han
Texas A&M University, USA

We develop, design, and fabricate an electrorotation device with eight pairs of electrodes to measure cell rotation rate. To increase accuracy of electrorotation measurement, nDEP force was used to trap cells in the middle of electrodes.

M3P.020 MICROFLUIDICALLY INTEGRATED SERS ACTIVE CELL TRAP ARRAY FOR SENSITIVE ANALYSIS OF RED BLOOD CELLS

Orsolya Hakkel, István Rigó, Miklós Veres, and Péter Fürjes
Hungarian Academy of Sciences, HUNGARY

Surface enhanced Raman spectra of normal blood sample were recorded and analysed by using a periodic SERS active structure integrated in microfluidic injection system. Vertically perforated membranes were fabricated by 3D micromachining and applied for subsequent sample preparation (filtration / cell entrapment) and Raman Spectroscopy. SERS spectra of blood plasma and trapped red blood cells (RBCs) were recorded and compared to verify the functionality of the bioanalytical microsystem.

M3P.021 OXYGEN MICROSENSOR ARRAY TO STUDY SPATIAL EFFICACY OF PHOTODYNAMIC THERAPY IN VITRO

Julia Marzioch, Jochen Kieninger, Andreas Weltin, and Gerald A. Urban
University of Freiburg, GERMANY

We present a cell culture monitoring platform to study effects of photodynamic therapy (PDT). Differences in cellular respiration at the transition between treated and untreated tumor cells were detected. The sensor platform consists of a transparent microsensor chip with an array of electrochemical oxygen microsensors. Therewith more realistic in vitro studies of treatment efficiency and edge effects during PDT are possible by imitating the spatially limited exposure of the in vivo situation.

M3P.022 PCR AMPLIFIED DNAZYME-AMPLICONS FOR GENERIC SOLID-PHASE ANTIMICROBIAL RESISTANCE SCREENING

Bernd Peeters, Saba Safdar, Bram Carlier, Dragana Spasic, Devin Daems, and Jeroen Lammertyn
University of Leuven (KU Leuven), BELGIUM

A novel, generic solid-phase DNA sensor concept was developed, based on fiber optic surface plasmon resonance (FO-SPR) and PCR amplified DNAzyme activity. Improved levels of specificity and sensitivity were obtained down to picomolar concentrations. Moreover, the FO-SPR sensor enables AuNP amplified DNA target detection, independent of its sequence length. The FO-SPR sensor was demonstrated for MCR-2 gene detection, a gene important for the antimicrobial resistance in species such as E. Coli.

M3P.023 QUANTITATIVE MEASUREMENT OF CELL SURFACE EXPRESSION VIA MAGNETOPHORETIC CYTOMETRY

Ozgun Civelekoglu, Ningquan Wang, Mert Boya, Tevhide Ozkaya-Ahmadov, Ruxiu Liu, and Ali F. Sarioglu
Georgia Institute of Technology, USA

We report an integrated microfluidic flow cytometry platform utilizing a free-flow magnetophoresis and electrical sensing to quantitatively analyze surface expression of cells. Taken together, our system offers a highly-portable, frugal and electronic alternative to fluorescence-based flow cytometers.

M3P.024 SERS DETECTION OF A SINGLE NUCLEOBASE IN A DNA OLIGOMER USING A GOLD NANOPARTICLE DIMER

Koji Sugano, Katsunari Maruoka, Akio Uesugi, and Yoshitada Isono
Kobe University, JAPANIRAN

This paper reports surface enhanced Raman spectroscopy (SERS) of a single-stranded DNA toward a SERS-based DNA sequencing. Optimizing gold nanoparticle size we demonstrated the detection of a single adenine in a single DNA oligomer. The time transition of adenine and cytosine peaks reflects identification of adjacent bases in a DNA oligomer sequence, suggesting the possibility of one-by-one DNA sequencing with SERS.

M3P.025 STUDY ENDOTHELIAL CELL NETWORKING IN HYDROGEL UNDER OXYGEN GRADIENTS USING MICROFLUIDIC DEVICES

Heng-Hua Hsu[1,2], Ping-Liang Ko[1], Tse-Ang Lee[1], His-Chieh Lin[1], and Yi-Chung Tung[1]
[1]Academia Sinica, TAIWAN and [2]National Tsing Hua University, TAIWAN

We develop and optimize a microfluidic device capable of culturing cell within the three-dimensional hydrogel under oxygen gradients for studying vasculogenesis in vitro. The device provides an in vitro model for imitating vasculogenesis process under in vivo oxygen microenvironments in the three-dimensional matrix. It is a powerful platform to study 3D cellular behaviors under oxygen gradients for various biomedical studies.

M3P.026 THREE-DIMENSIONAL MICROELECTRODES ARRAY BASED ON VERTICALLY STACKED BEADS FOR MAPPING NEURONS' ELECTROPHYSIOLOGICAL ACTIVITY

Leandro Lorenzelli[1], Andrea Spanu[2], Severino Pedrotti[1], Mariateresa Tedesco[3], and Sergio Martinoia[3]
[1]Fondazione Bruno Kessler, ITALY, [2]University of Cagliari, ITALY, and [3]University of Genova, ITALY

Assessing the neural connectivity and monitoring the electrical activity of in vitro 3D neuronal complex cellular structures has become an important research objective that requires innovative platforms and fabrication approaches.We have investigated a customizable technique for developing 3D-vertical microelectrodes on standard planar MEAs in order to obtain innovative platforms for neurophysiological applications for understanding the neurons electrical interactions at 3D level.

M3P.027 ULTRASENSITIVE DETECTION OF AFLATOXIN B1 USING A POLYIMIDE-BASED PIEZORESISTIVE MICROCANTILEVER BIOSENSOR

Yuan Tian, Yang Wang, and Xiaomei Yu
Peking University, CHINA

We propose an ultrasensitive detection of aflatoxin B1 using a piezoresistive microcantilever biosensor, which is composed of heavy doped piezoresistive layer, top polyimide passive layer and bottom silicon oxide passive layer. The fabricated PI/Si/SiO_2 microcantilever shows a steady output with less than 1 μV@3V fluctuation in PBS buffer. Detections on aflatoxin B1 with a minimum concentration of 1 ng/mL were achieved.

Tuesday - Bio-Sensors and Bio-Microsystems

T3P.010 A FLOW THROUGH DEVICE FOR SIMULTANEOUS DIELECTROPHORETIC CELL TRAPPING AND AC ELECTROPORATION

Meera Punjiya, Hojatollah Rezaei Nejad, and Sameer Sonkusale
Tufts University, USA

Cell isolation and selected transfection of those isolated cells is integral to single-cell analyses platforms. We present an electrode geometry suitable for simultaneous nDEP trapping and AC electroporation of cells and experimentally validate that cells can experience both phenomena simultaneously in a controlled manner. We demonstrate the geometry through numerical simulation and observation of Calcein AM dye leaching from human embryonic kidney cells.

T3P.011 A NEW DETECTION OF BIOMARKER MOLECULE OF ALPHA-SYNUCLEIN FOR PARKINSON DISEASE BY PHOSPHOLIPID LIPOSOME-IMMOBILIZED CANTILEVER MICROSENSOR WITH TEMPERATURE STABILIZATION

Ryoko Kobayashi[1], Masanori Sawamura[2], Hodaka Yamakado[2], Masayuki Sohgawa[3], and Minoru Noda[1]
[1]Kyoto Institute of Technology, JAPAN, [2]Kyoto Unviversity, JAPAN and [3]Niigata University, JAPAN

We have measured, for the first time, chronological behavior of alpha-synuclein (aSyn) as causative agent for Parkinson Disease by liposome-immobilized cantilever microsensor. Our goal is to detect aggregated, not monomeric, forms of aSyn in its initial stage, which is most toxic, in patient's cerebrospinal fluid (CSF). The aSyn aggregates in PBS were successfully detected compared to CSF of healthy person. With a developed temperature stabilization, aSyn was detected down to 100 pM.

T3P.012 A PORTABLE, AUTOMATIC MICROFLUIDIC SYSTEM FOR RAPID PERSONALIZED ANTIBIOTIC SCREENING

Wen-Bin Lee[1], Kuo-Wei Hsu[1], Huey-Ling You[2], Mel S. Lee[2], and Gwo-Bin Lee[1]
[1]National Tsing Hua University, TAIWAN and [2]Chang Gung University, TAIWAN

This study reported a portable microfluidic system which can be used to automatically perform antibiotic screening with single antibiotic, double antibiotic combinations and even triple antibiotic combinations on clinical isolated bacteria strains.

T3P.013 CHIP BASED MICROELECTROCHEMICAL CELL ARRARY FOR WHOLE-CELL PATCH-CLAMP RECORDING

Tianyang Zheng[1], Gerhard Baaken[2], Jürgen Rühe[2], Jan C. Behrends[2], and Rong Zhu[1]
[1]Tsinghua University, CHINA and [2]University of Freiburg, GERMANY

We propose a novel planar microchip integrated with microelectrochemical cell array to more toward a feasible solution for ion channel screening with high resolution and long life-time. Through this chip based method, long term current recording through biological cell membrane is achieved with good electrical sealing resistance. In addition, with no need for complex fluidic connections, this method allows for an easy operation and further miniaturization of the measuring system.

T3P.014 DEVELOPMENT OF A CROSSING CONSTRICTION CHANNEL BASED MICROFLUIDIC CYTOMETRY ENABLING THE HIGH-THROUGHPUT QUANTIFICATION OF SINGLE-CELL ELECTRICAL PHENOTYPES

Yi Zhang[1], Yang Zhao[1], Deyong Chen[1], Ke Wang[1], Yuanchen Wei[1], Ying Xu[2], Hua Wei[1], Guoqing Zhang[1], Chengjun Huang[1], Junbo Wang[1], and Jian Chen[1]
[1]Chinese Academy of Sciences (CAS), CHINA and [2]Shanghai Jiao-Tong University School of Medicine, CHINA

This paper presents a high-throughput impedance cytometry enabling cellular electrical (e.g. specific membrane capacitance and cytoplasm conductivity) characterization of large populations (>100,000 cells) with analysis rates higher than 100 cells/second. This impedance cytometry can distinguish paired tumor cell lines isolated from the same tumor type. This technique adds a new marker-free dimension to flow cytometry in single-cell analysis.

T3P.015 DIGITAL MIRNA DETECTION BASED ON TARGET CYCLING-INDUCED FRET SIGNAL AMPLIFICATION

Bin Wang, Kaijian Zhu, Zheng You, and Dahai Ren
Tsinghua University, CHINA

This paper reports a novel miRNA detection method based on target cycling-induced FRET signal amplification and droplet microfluidics. It allows, for the first time, digital miRNA detection with high selectivity and sensitivity at single-molecule level theoretically. In this method, the full use of miRNA sequence information made the hybridization between targets and DNA probes unique and sensitive, offering high capacity to distinguish single-base mismatches.

T3P.016 GOLD NANOGAP INTERDIGITATED ARRAYS FOR REDOX CYCLING AMPLIFIED DOPAMINE DETECTION

Elmar Laubender[1], Volha Matylitskaya[2], Elisabeth Kostal[2], Stephan Kasemann[2], Gerald A. Urban[1], Stefan Partel[2], and Can Dincer[1]
[1]University of Freiburg, GERMANY and [2]Vorarlberg University of Applied Sciences, AUSTRIA

We present the highly sensitive detection of dopamine using gold nanogap IDAs with redox-cycling amplification. The IDA fabrication process allows tuning of the nanogap sizes. Through the combination with a facile electrochemical activation and amperometric multistep protocol, fouling of the gold electrode surface can be prevented. Employing our flexible and inexpensive method, DA monitoring with a short acquisition period and a detection limit less than 200 nM is successfully demonstrated.

T3P.017 HIGH-THROUGHPUT INTERDIGITATED ELECTRODE ARRAY ON MICROGROOVE-PATTERNED CANTILEVER TO MEASURE ELECTRO-MECHANICAL PROPERTIES OF CARDIOMYOCYTES

Pooja P. Kanade, Nomin-Erdene Oyunbaatar, and Dong-Weon Lee
Chonnam National University, KOREA

We present a new device that can simultaneously measure the mechanical force and electrophysiology of cardiac cells using a new cantilever device that is integrated with an interdigitated electrode array (IDE). On the cantilever, microgroove patterns are formed which positively influences the maturation and alignment of cardiac cells. The fabricated cantilever device can measure impedance of the cardiomyocytes as well as the displacement that occurs because of the cardiomyocyte contractions.

T3P.018 SINGLE CELL ANALYSIS MICROFLUIDIC DEVICE FOR CELL LINE OPTIMISATION IN UPSTREAM CELL CULTURE PROCESSING BIOPHARAMCEUTICAL APPLICATIONS

Damien King, Jonathan Loftus, Raphaela Ferreira, Kevin Keating, Tom Glennon, Josh Fallon-Doran, Ricardo Valdés-Bango Curell, Berta Capella Roca, Padraig Doolan, and Jens Ducrée
Dublin City University, IRELAND

A microfluidic single cell analysis device is reported within that identifies optimal protein producing cells within a population, subsequently isolating and culturing them for efficient cell line development. This lab on a disc device first centrifugally sediments a cohort of suspended CHO cells into an array of 1,200 traps at single-occupancy distribution where they can be individually analysed for their protein expression via their fluorescence.

T3P.019 LOW-MELTING ALLOY MICROFLUIDIC ELECTRODE BASED ON HYDROPHOBIC VALVE AND ITS APPLICATION IN COULTER COUNTER

Dong Yang, Wenpeng Xun, Huicheng Feng, and Honglong Chang
Northwestern Polytechnical University, CHINA

This paper reports a method to fabricate low-melting point alloy (LMPA) electrodes in polydimethylsiloxane (PDMS) channels. The melting alloy can be automatically aligned on the side of the main channel without blocking it. A coulter counter microfluidic chip is fabricated using this method and a coefficient variation (CV) of about 1.99% is obtained on 10-μm beads.

T3P.020 MICROCHANNEL-INTEGRATED SANDWICH 3D TRIPLE ELECTRODES FOR ENHANCED DETECTION OF MYOGLOBIN AS A CANCER BIOMARKER

Deepti Sharma, Jongmin Lee, and Heungjoo Shin
Ulsan National Institute of Science and Technology (UNIST), KOREA

We report development of an electrochemical redox cycling-based immunosensor using microchannel-integrated sandwich 3D triple electrode system. The triple electrodes fabricated using C-MEMS. Monoclonal antibody (mAb) was immobilized on only suspended mesh electrode via diazonium salt and IDA electrodes were employed for efficient redox-cycling of redox species (PAP/PQI). The microchannel integration facilitated 8-fold better LOD as compare to bulk, preventing diffusion of PAP to bulk solution

T3P.021 MULTI USE MICROFLUIDIC BIOSENSORS FOR CONTINUAL MONITORING OF BIOMARKERS FROM MICROPHYSIOLOGICAL SYSTEMS

Farnaz Lorestani, Ali Khademhosseini, and Mehmet R. Dokmeci
University of California, Los Angeles, USA

Despite the recent progress in organs on a chip, there are very few efforts to monitor activity of cells in these platforms. We present a novel multi use biosensor technology for in-line detection of soluble biomarkers for long-term monitoring of human organoids. Electrical pulse based cleaning of the sensor surface was followed with subsequent functionalization of the sensors for continual biosensing for up to 30 times.

T3P.022 OXYGEN VACANCY ENGINEERED TUNGSTEN OXIDE HYDRATE NANOSHEETS COUPLING WITH NITROGEN DOPED GRAPHENE QUANTUM DOTS FOR ULTRASENSITIVE PHOTOELECTROCHEMICAL DETECTION OF ESCHERICHIA COLI

Jiuhai Wang, Ding Jiang, Yadi Fan, and Mo Yang
Hong Kong Polytechnic University, HONG KONG

We develop an innovative Photoelectrochemical (PEC) aptasensor platform for rapid detection of Escherichia coli (E. coli) with high sensitivity. By coupling defective tungsten oxide hydrate nanosheets and nitrogen-doped graphene quantum dots (N-GQDs) via one-pot hydrothermal method, this nanocomposite provided significant enhanced photocurrent compared to other pure materials and defective-deficient materials owing to the efficient charge transfer and the extended photo-response.

T3P.023 PERFORMANCE STUDY OF MICROSIEVES WITH DIFFERENT PORE GEOMETRIES BASED ON MAGNETIC CELL CENTRIFUGE PLATFORM

Xinyu Wu[1], Lin Wang[1], Zhongyag Bai[1], Guangchao Cui[1], Mengzheneg Yang[1], Qing Yang[1], Bo Ma[2], Jian Ye[3], Frederik Ceyssens[4], and Lianggong Wen[1,2]
[1]Beihang University, CHINA, [2]Chinese Academy of Sciences (CAS), CHINA,
[3]Shanghai Jiao Tong University, CHINA, and [4]University of Leuven (KU Leuven), BELGIUM

We compare the influence of different pore geometries of microsieves towards the Magnetic Cell Centrifuge Platform (MCCP), which demonstrates the comparison of system performance with silicon-based sieves combining the magnetic-labeling cell separation mechanism with the size-based method. The experimental results show that slot pores allow higher flow rate under certain inlet pressure. In comparison, the round-pore sieve yields better cell retention rate and capture efficiency.

T3P.024 RAPID ASSESSMENT OF COMBINED DROP ON DEMAND AND EXTRUSION-BASED BIOPRINTING WITH CONTROLLED SHEAR STRESSES AND HIGH SHAPE FIDELITY

Fritz Koch[1], Maximilian Wehrle[2], Kevin Tröndle[1], Peter Koltay[1], Günter Finkenzeller[2], Roland Zengerle[1], and Stefan Zimmermann[1]
[1]University of Freiburg, GERMANY and [2]Universitätsklinikum Freiburg, GERMANY

We present a novel combination of microsystems for drop on demand (DoD) and extrusion-based bioprinting to generate patterns of cells with an accuracy of less than 100 µm inside large hydrogel volumes. To limit the multitude of parameters during bioprinting processes, a method for rapid process assessment was developed to determine the printing temperature, flow rate and nozzle size with regard to the biological and mechanical requirements from basic rheological measurements.

T3P.025 SILICON NANOWIRES AS BIOCOMPATIBILE ELECTRONICS-BIOLOGY INTERFACE

Paola Piedimonte, Sergio Fucile, Cristina Limatola, Massimiliano Renzi, and Fabrizio Palma
Sapienza University of Rome, ITALY

An innovative approach for bioelectric signals sensing is proposed. It is based on Silicon NanoWires (SiNWs) grown at low-temperature (200°C) thus ICs compatible. Our preliminary results show biocompatibility and neutrality of SiNWs used as seeding substrate for cells in culture. With this technology, we aim to produce a compact device allowing localized and high signal/noise recordings of a large variety of bio-signals from networks of excitable cells or subdomains of a cell membrane.

T3P.026 THE COOPERATVE MOTILITY OF MICROTUBULES ON NANO-PATTERNED KINESIN-1 TURF

Tamanna Farhana, Takiopaul Kaneko, and Ryuji Yokokawa
Kyoto University, JAPAN

We emphasized here, how the spatial arrangements of kinesins in nanoscale range enables to influence the motile behavior of microtubules (MTs) using the recently developed nano-patterning method. Here, we have demonstrated the coordinated motion of MTs that emerged only by the physical interactions of MTs and patterned kinesins rather than implication of any binding or depleting force.

T3P.027 UNIQUE IMPEDAMETRIC CELL DEFORMABILITY ASSAY USING A MULTI-CONSTRICTION MICROFLUIDIC BIOSENSOR

Parham Ghassemi and Masoud Agah
Virginia Polytechnic Institute and State University, USA

A microfluidic device consisting of a multi-constriction microfluidic channel embedded with biosensors analyzes bioelectrical and biomechanical attributes to differentiate cancer cells of varying invasiveness and their normal non-tumorigenic counterparts. The system is the first that utilizes sensors for rapid measurements of cell velocities and bioimpedance as they transit through iterative constrictions.

Wednesday - Bio-Sensors and Bio-Microsystems

W3P.009 A HANDHELD AND BATTERY-POWERED REALTIME MICROFLUIDIC POLYMERASE CHAIN REACTION (PCR) AMPLIFICATION DEVICE

Dae-Sik Lee[1], Ok Ran Choi[2], and Yu Jin Seo[2]
[1]Electronics and Telecommunication Research Institute (ETRI), KOREA and [2]GeneSystem, KOREA

This paper reports a handheld and battery-powered polymerase chain reaction (PCR) system using a polyimide film-based microfabricated heating modules and polymer film microfluidic chambers, with a very low power consumption, compared to state of the art. The device will be, to the best of our knowledge, the smallest and very fast real-time microfluidic amplification and quantification of deoxyribonucleic acid (DNA).

W3P.010 A NOVEL CORTISOL BIOSENSOR BASED ON THE CAPACITIVE STRUCTURE OF HAFNIUM OXIDE: APPLICATION FOR HEART FAILURE MONITORING

Hamdi Ben Halima[1], Nadia Zine[1], Juan Gallardo-Gonzalez[1], Abdelhamid El Aissari[2], Monique Sigaud[1], Albert Alcacer[3], Joan Bausells[3], and Abdelhamid Errachid[1]
[1]Institut de Science Analytique, FRANCE, [2]Université Claude Bernard Lyon, FRANCE, and [3]Institut de Microelectronica de Barcelona, SPAIN

Assessing cortisol level in human bodies has become an essential tool to recognize heart failure. In this work, the label-free detection of cortisol using a novel capacitive substrate based on hafnium oxide (HfO_2) was accomplished. We studied the interaction between the cortisol with its corresponding polyclonal antibody, and the detection event was followed by electrochemical impedance spectroscopy. Cortisol was detectable between a wide range of concentration from 2 ng/mL to 50 ng/mL.

W3P.011 A NOVEL STAGE-TOP-BIOREACTOR INTEGRATED WITH NANO-TEXTURED POLYDIMETHYLSILOXANE (PDMS) DIAPHRAGM

Yun-Jin Jeong, Bong-Kee Lee, Eung-Sam Kim, and Dong-Weon Lee
Chonnam National University, KOREA

We propose a new type of stage-top-bioreactor capable of cell culture, structural & mechanical stimulation, and real-time monitoring of growth cells. A function well plate placed in the middle of the stage-top-bioreactor effectively stimulates growth cells through the deformation of a surface-textured PDMS diaphragm. In addition, the unique PDMS diaphragm structure allows alignment in one direction through the nano-textures as well as the mechanical stimulation.

W3P.012 AN APTAMER BASED SANDWICH ASSAY FOR SIMULTANEOUS DETECTION OF MULTIPLE CARDIOVASCULAR BIOMARKERS ON A MULTILAYERED INTEGRATED MICROFLUIDIC SYSTEM

Anirban Sinha[1], Priya Gopinathan[1], Yi-Da Chung[1], Shu-Chu Shiesh[2], and Gwo-Bin Lee[1]
[1]National Tsing Hua University, TAIWAN and [2]National Cheng Kung University, TAIWAN

We developed a microfluidic system for fast diagnosis of CVDs biomarkers and could serve a step forward where an antibody may be substituted by an aptamer towards the next generation CVDs sensors and widely applicable in next-generation point-of-care diagnostics.

W3P.013 COMPREHENSIVE, HIGH THROUGHPUT SCREENING OF NEURON BEHAVIOR ON GRADIENT MICRO-ALIGNMENT TOPOGRAPHIES

Ryan C. McNaughton, Yuda Huo, Guicai Li, Xiaoguang Zhao, Hengye Man, and Xin Zhang
Boston University, USA

We develop and fabricate a linear, anisotropic gradient microridge/groove array with a PDMS micromolding technique that allows more efficient analysis of neurons in variable mircoenvironments. Immunofluorescence staining of hippocampal neurons is implemented to compare the morphological and synaptic network variations induced across the gradient geometry.

W3P.014 DEVELOPMENT OF A MULTI CHANNEL PIEZOELECTRIC FLEXURAL PLATE-WAVE BIOMEMS-SENSOR FOR RAPID POINT-OF-CARE DIAGNOSTICS

Matthias Wiemann[1], Christian Walk[1], Dieter Greifendorf[1], Jens Weidenmüller[1], Andreas Jupe[1], and Karsten Seidl[1,2]
[1]Fraunhofer IMS, GERMANY and [2]University of Duisburg-Essen, GERMANY

A Respiratory Syncytial Virus is responsible for a high rate of post-neonatal deaths. An early diagnosis with accurate and fast detection is vital for an effective treatment. Common diagnostics for the identification of unknown pathogens are time consuming. Here, a piezoelectric flexural plate wave Bio-MEMS sensor utilising multi resonating membranes was developed. The experimental results show a frequency shift of a functionalised membrane of up to 14 Hz/nM RSV chemokines in complex media.

W3P.015 EVALUATION OF THE BINDING OF PD-1 ANTIBODY AND ANTIGEN USING NANO-SENSORS

Jingjie Sha, Fangzhou Fu, Bing Xu, Ke Chen, and Xiao Li
Southeast University, CHINA

We use solid-state nanopore as a single molecule method to detect the binding of PD-1 antibody and antigen. Using PD-1 antibody modified nanopore, the antibody-antigen complexes are detected and distinguished with PD-1 protein and its antibody through the relative current drop analysis. The binding rate of the complexes are found changed with variation of binding temperature.

W3P.016 IDENTIFICATION OF URINE ODOUR USING CMOS-BASED METAL OXIDE RESISTIVE GAS SENSORS

Yuxin Xing, Marina Cole, and Julian Gardner
University Warwick, UK

We use an array of metal oxide gas sensors and artificial intelligence to separate out the smell of urine (synthetic) from the odorous headspace of its major components: acetone, ammonia, and ethyl acetate. The sensors employed were two n-types (WO3 and SnO_2 doped with Pd/Pt) and one p-type (CuO). Sensor responses were classified using a two-layer perceptron model with back propagation. The AI model had an overall accuracy of 100% for identifying synthetic urine and 91.1% for all components.

W3P.017 INHIBITION OF MDR/MRSA BACTERIAL BIOFILMS BY THE ANTIMICROBIAL PEPTIDES ESCULENTIN 1-A AND OH-CATH-30 MONITORED BY A THERMAL SENSOR SYSTEM IN REAL-TIME

Tobias Wieland[1], Krishan Kotthaus[1], Helena Gmoser[1], Julia Assmann[2], and Gerald Anton Urban[1]
[1]University of Freiburg, GERMANY and [2]Frei University Berlin, GERMANY

A bacterial biofilm forms on a thin thermal sensor membrane, on which a small chromium heater generates a 40 Hz steady sinusoidal heat signal. The presented measurement method utilized for this application relies on the change in thermal properties, specific thermal conductivity and volumetric heat capacity, which leads to different measurement results due to maturation of biofilm. We measured a simultaneous start of biofilm formation which was delayed by three or more hours when using the AMP.

W3P.018 MAGNETIZATION-FREE MICRO-TAG FOR BIOMETRIC IDENTIFICATION UNDER WATER

Kohei Oguma[1], Tasuku Sato[1], Tomohiro Kawahara[2], Yoshikazu Haramoto[3], and Yoko Yamanishi[1]
[1]Kyushu University, JAPAN, [2]Kyushu Institute of Technology, JAPAN and
[3]National Institute of Advanced Industrial Science and Technology (AIST), JAPAN

We proposed a novel magnetization-free micro-magnetic tag and fabricated with low cost to make a tracking living bodies under water condition for biometric identification within short time. Magneto-optics was employed as a high throughput sensing. FEM analysis has successfully optimized the configurations of external magnetic field and additional Yoke module using double layer structure, which suggest that the sensing distance can be extended as twice as that of the conventional results.

W3P.019 MICROCRATER-ARRAYED CELL CHIPS TO BOOST THE ANTI-CANCER DRUG ADMINISTRATION IN ZEBRAFISH TUMOR XENOGRAFT MODELS

Ching-Te Kuo[1], Yu-Sheng Lai[1], Andrew M. Wo[1], Benjamin P.C. Chen[2], and Hsinyu Lee[1]
[1]National Taiwan University, TAIWAN and [2]University of Texas Southwestern Medical Center, USA

We present a microcrater-arrayed cell chip integrated with an automatic liquid handling system for the rapid evaluation of optimal drug combinations to treat cancers. Results demonstrates that our approach to identify the potent drug administration in zebrafish tumor xenograft models is more accurately than conventional 96-well plate assays.

W3P.020 NEXT-GENERATION ORGAN-ON-CHIP SYSTEM FOR DIRECTIONAL CONTROL OF CULTURE CONDITIONS AND METABOLIC MONITORING OF TUMOR ORGANOIDS

Johannes Dornhof[1], Jochen Kieninger[1], Jochen Maurer[2], Gerald A. Urban[1] and Andreas Weltin[1]
[1]University of Freiburg, GERMANY and [2]University Hospital Aachen (UKA), GERMANY

This work presents an organ-on-chip platform with integrated electrochemical microsensors fabricated by thin-film technology for compartmentalized 3D culturing of patient-derived breast cancer stem cells. By this on-chip integration of microsensors, the microfluidic platform allows advanced control and in situ measurement of both culture conditions (oxygen) and cell metabolism (lactate), enhancing the state-of-the-art, as the transparent chip also allows characterization with optical methods.

W3P.021 PATTERNING OF DIFFERENT MOTOR PROTEINS USING AQUEOUS TWO-PHASE SYSTEM

Tomohiro Nakagawa, Shimpei Oohara, Tamanna I. Farhana, and Ryuji Yokokawa
Kyoto University, JAPAN

We developed a method to pattern different motor proteins by polymeric aqueous two phase systems: ATPS. This system hinder amalgamation of proteins during fixation, which leads to their selective patterning. The applicability of this method was investigated concerning the function of motors in individual polymers and their constructed ATPS. The pattering is evaluated by moving microtubule's polarity. This method will contribute to study the cooperativity of different motor proteins in vivo.

W3P.022 PRINTED ELECTROPHORESIS-DRIVEN DNA SEPARATOR

Natascha K. Heinsohn[1,2], Robert R. Niedl[2] and Carsten Beta[1],
[1]Universität Potsdam, GERMANY and [2]Diamond Inventics GmbH, GERMANY

In this work we established a method for detecting directed DNA motion within a biopolymer network. Real time monitoring could be successfully implemented using screen-printed electrodes. The aim of this research is the characteristic pattern determination of biological samples under the influence of an electrical field. This will allow the extension of present DNA detection and verification methods in disposable on-site analytical test systems.

W3P.023 RATIOMETRIC MULTIPLEXED PCR ASSAY ON A PORTABLE PLATFORM FOR BACTERIAL IDENTIFICATION FROM URINE

Fan-En Chen, Alexander Y. Trick, Wen Hsieh, Dong Jin Shin, Liben Chen, Emily Chang, Aniruddha Kaushik, and Tzsa-Huei Wang
Johns Hopkins University, USA

We present a fully integrated, portable, and multiplexed real-time PCR platform capable of identifying up to 6 bacterial species directly from urine samples. Rapid identification of pathogens at the point of care (e.g., outpatient settings) with our platform can inform targeted treatments to combat the emergence of antibiotic resistant pathogens.

W3P.024 SHRINK-INDUCED HIGHLY SENSITIVE DOPAMINE SENSOR BASED ON SELF-ASSEMBLY GRAPHENE ON MICROELECTRODE

Guihua Xiao[1], Jungyoon Kim[1], Xinxia Cai[2], and Tianhong Cui[1]
[1]University of Minnesota, USA and [2]Chinese Academy of Sciences (CAS), CHINA

This paper presents a highly sensitive dopamine microelectrode fabricated by self-assembly of graphene on a gold electrode with polystyrene shrink polymer substrate. Nano graphene wrinkles and gaps are formed on the rough gold layer after shrinkage, significantly enhancing the sensor performance for dopamine detection.

W3P.025 TEAR DIAGNOSIS FOR DIABETIC RETINOPATHY USING AN OPTOELECTROKINETICALLY DRIVEN BEAD-BASED IMMUNOSENSOR

Han-Sheng Chuang[1], Jen-Yi Wang[1], Jae-Sung Kwon[2], and Sheng-Min Hsu[3]
[1]National Cheng Kung University, TAIWAN, [2]Incheon National University, KOREA, and [3]National Cheng Kung University Hospital, TAIWAN

A noninvasive and efficient optoelectrokinetically-driven diagnostic technique was developed in this study for rapid diabetic retinopathy screening. Analyte was collected from human tear. LCN1 and VEGF were indentified as two target biomarkers. The limit of detection reached nearly 110 pg/mL. A preclinical evaluation with an accuracy of 94.7% was also conducted. The optoelectrokinetically-driven bead-based immunosensor provides an insight to the tear diagnosis of more other diseases.

W3P.026 THIN FILM SENSOR PLATFORM FOR ON-CHIP DETECTION OF FLUORESCENCE-BASED APTAMER ASSAY

Francesca Costantini, Nicola Lovecchio, Augusto Nascetti, Giampiero de Cesare, and Domenico Caputo
University of Rome, ITALY

This work presents a bio-microsystem, which couples thin film optoelectronic devices (amorphous silicon photosensors and a thin film interferential filter) with chemical surface treatment for the on-chip detection of fluorescence-based aptamer assay. The platform offers several advantages such as: use of a small volume of sample, low cost, sensitivity comparable with systems based on antibodies, response time less than 10 min and portability.

W3P.027 VISUAL AND REAL-TIME BIOSENSOR BASED ON PLASMONIC METAMATERIALS FOR BIOTIN-AVIDIN-SYSTEM DETECTION

Jia Zhu[1], Guanzhou Lin[2], Runhua Wang[1], Yun Huang[1], Zhuojie Chen[1], Xiaoyu Chen[1], Peimin Lu[2], and Wengang Wu[1]
[1]Peking University, CHINA and [2]Fuzhou University, CHINA

We present a visual and real-time sensing strategy for the detection of the biotin-avidin-system, which is a powerful tool in biological sciences. When a monomolecular layer of thiolated biotin and streptavidin bonding to the surface of the nanostructure successively, the color of the metamaterials changes from red to violet and then loden. This sensing strategy offers new opportunities for convenient detection of proteins, nucleic acids and lipids.

Monday - Chemical and Environmental Sensors and Microsystems

M3P.028 3D-INTEGRATED MULTI-SENSOR DEMONSTRATOR SYSTEM FOR ENVIRONMENTAL MONITORING

Anton Köck[1], Robert Wimmer-Teubenbacher[1], Florentyna Sosada-Ludwikovska[1], Karl Rohracher[2], Ewald Wachmann[2], Martin Herold[3], Ton van Welden[4], Jong Min Kim[5], Zeeshan Ali[6], Anneliese Poenninger[7], Markus Stahl-Offergeld[8], Hans-Peter Hohe[8], Jürgen Lorenz[9], Tobias Erlbacher[9], Guido Dolmans[10], Peter Offermans[10], Marianne Vandecasteele[10], Olena Yurchenko[11], Oliver von Sicard[12], Roland Pohle[12], Florin Udrea[13], Claudio Falco[13], Denis Flandre[14], David Bol[14], Elisabetta Comini[15], Dario Zappa[15], Julian Gardner[16], Marina Cole[16], Jan Theunis[17], Jan Peters[17], and Alan Baldwin[18]
[1]Materials Center Leoben Forschung GmbH, AUSTRIA and [2]ams AG, AUSTRIA, [3]ams Sensor Solutions Germany GmbH, GERMANY, [4]Boschman Technologies BV, THE NETHERLANDS, [5]University of Oxford, UK, [6]ams Sensor UK Ltd., UK, [7]EVGroup, AUSTRIA, [8]Fraunhofer Institute for Integrated Circuits (IIS), GERMANY, [9]Fraunhofer Institute for Integrated Systems and Device Technology (IISB), GERMANY, [10]Stichting IMEC, THE NETHERLANDS, [11]University of Freiburg, GERMANY, [12]Siemens AG, GERMANY, [13]University of Cambridge, UK, [14]Université Catholique de Louvain, BELGIUM, [15]Universita Degli Studi Di Brescia, ITALY, [16]University of Warwick, UK, [17]VITO NV, BELGIUM, and [18]Samsung R&D Institute, UK

This paper summarizes the outcome of the EC FP7 project MSP - Multi Sensor Platform for Smart Building Management. A full manufacturing chain for 3D system integration of highly sophisticated sensor devices on a CMOS electronic platform chip has been developed. The final multi-sensor demonstrator system integrates a total of 57 sensors comprising gas sensors as well as optical sensors for ultraviolet, visible and infrared light, and is a worldwide unique sensor system.

M3P.029 A HIGH-SENSITIVITY MICROFLUIDIC CHIP CALORIMETER FOR BIOCHEMICAL REACTION MONITORING APPLICATIONS

Jianze Huang, Congchun Zhang, Guifu Ding, Zhuoqing Yang, Xiaolin Zhao, Yang Liu, Zhiyong Tang, Xiufeng Shao, Shenyong Yang, and Xingkai Lin
Shanghai Jiao Tong University, CHINA

We developed a high-sensitivity chip calorimeter for biochemical reaction detection. The device consists of a flexible thermal sensor based on polyimide(PI) substrate and PDMS microfluidic chambers.The device has a high heat power sensitivity of 5.3V/W and a thermal response time about 0.93s which is good enough for real time reaction heat monitoring. The calorimeter have prospects for many biochemical applications.

M3P.030 A MINIATURIZED OPTICAL SENSOR FOR FIRE SMOKE DETECTION

Gabriel Jobert[1], Maryse Fournier[1], Pierre Barritault[1], Salim Boutami[1], Jérémie Auger[2], Adrien Maillard[2], Julien Michelot[3], Pierre Lienhard[3], Sergio Nicoletti[1], and Laurent Duraffourg[1]
[1]University of Grenoble-Alpes, CEA-LETI, FRANCE, [2]FARE, FRANCE, and [3]Pyxalis, FRANCE

We present an innovative miniaturized optical smoke sensor based on particle light scattering imaging. A CMOS imager collects the light diffracted by the smoke particles. The diffraction pattern can be interpreted using Mie's theory. The specific signatures of interactions between the light and the smoke allows differentiating the type of fires at very low concentration of particles. We will describe the simulations, fabrication and characterization results of this novel sensor.

M3P.031 AEROSOL DEPOSITION METHOD - A PROMISING NOVEL METHOD TO PRODUCE CERAMIC GAS SENSOR FILMS AT ROOM TEMPERATURE

Ralf Moos, Murat Bektas, Simon Püls, Gunter Hagen, Jaroslaw Kita, and Jörg Exner
University of Bayreuth, GERMANY

The Aerosol Deposition Method (ADM, also called Room Temperature Impact Consolidation, RTIC) allows producing dense ceramic films completely without any high-temperature process directly from an initial ceramic powder on almost any substrate material. This contribution gives examples for applications of the ADM in the field of gas sensing. A new type of temperature independent oxygen sensor will be discussed in particular.

M3P.032 AN IN-PLANE MICRO-HOTPLATE FOR MEMS-BASED H_2S SENSOR

Gaoqiang Niu[1], Changhui Zhao[1], Huimin Gong[1], Yushen Hu[1,2], Yulong Zhang[1], Zhitao Zhou[3], Tiger H. Tao[2], and Fei Wang[1]
[1]Southern University of Science and Technology, CHINA, [2] Hong Kong University of Science and Technology and [3]Chinese Academy of Sciences (CAS), CHINA

This paper reports a H2S gas sensor with in-plane micro-hotplate fabricated by MEMS process. Both heating and testing electrodes are designed in the same plane, which improves the heating efficiency and simplify the fabrication process. With a step voltage control, fast response and recovery processes have been achieved for H2S detection at low concentration of 1ppm. The MEMS micro-hotplate could be useful to improve the recovery rates as well as the selectivity of the gas sensors.

M3P.033 AN OPTIMIZED NANOANTENNA PLATFORM FOR SURFACE ENHANCED MID-INFRARED SENSING

Jingxuan Wei, Dihan Hasan, and Chengkuo Lee
National University of Singapore, SINGAPORE

We develop generalized guidelines for the design of plasmonic metasurface sensor. Besides enhanced near-field intensity, the sensitivity is revealed to also be dependent on two unnoticed parameters, i.e. external and internal damping rates. By folding the mostly used nanorod antennas to be a darker mode, the sensitivity can be increased by 25 and 2 times for transmission and reflection modes, respectively.

M3P.034 COMBINED CONDUCTIVITY AND GRAVIMETRIC RESONANT GAS SENSOR FOR HIGH-TEMPERATURE APPLICATIONS

Sebastian Schroeder and Holger Fritze
Clausthal University of Technology, GERMANY

Monitoring specific gas species in heat treatment processes enable to evaluate the state of components being processed. Therefore, a bulk acoustic wave gas sensor based on high temperature stable piezoelectric transducers and thin metal oxide sensor films is developed. Simultaneous determination of changes in electrical and gravimetric properties of SnO_2, TiO_2 and $(Pr,Ce)O_2$ films enables to distinguish CH_4 and C_2H_4 in inert gas and strongly reducing atmospheres at temperatures up to 900 °C.

M3P.035 CSRR INTEGRATED MICROWAVE HUMIDITY SENSOR BASED GO@MXENE FOR BREATH MONITORING

Hairong Kou, Qiulin Tan, Lei Zhang, Jijun Xiong, and Wendong Zhang
North University of China, CHINA

We develop a microwave humidity sensor with a complementary split ring resonator (CSRR) based on Go@MXENE composite material, which can be used to monitor human breath in real-time. The CSRR structure can reduce the size of sensor. The sensitivity of resonant frequency and intensity with a wide humidity range from 10% to 95% RH can be improved by using the Go@MXENE composite material as sensitive material of humidity.

M3P.036 DESIGN AND EVALUATION OF AN ELECTRODE SEPARATED QUARTZ CRYSTAL MICROBALANCE ARRAY AS A DISPOSABLE WEIGHING DISH

Shunya Uchiki, Ikuto Sato, Masayuki Sohgawa, and Takashi Abe
Niigata University, JAPAN

This paper describes a new monolithic quartz-crystal microbalance (QCM) array as a disposable weighing dish;this microbalance contains electrodes on the sensing side and no electrodes on the opposing side. In this sensor, excitation electrodes are positioned on a glass plate that is separate from the dish. The optimized configuration of the monolithic QCM array relative to the crystallographic x-axis of the quartz plate is revealed for the first time.

M3P.037 FABRICATION OF PLATINUM FUNCTIONALIZED ZINC OXIDE NANORODS FOR HIGH-PERFORMANCE ACETYLENE GAS SENSOR INTEGRATED WITH MICROHEATER

Vijay V. Kondalkar, Le Thai Duy, Hyungtak Seo, and Keekeun Lee
Ajou University, KOREA

we demonstrated novel nanohybrids of Pt functioned Al_2O_3/ZnO core-shell nanorods (NRs) for real-time humidity-independent acetylene gas sensor. The fabricated novel nanohybrids of Pt functionalized Al_2O_3/ZnO core-shell NRs based sensor exhibits an ultrahigh response toward 1 ppm acetylene with faster response and recovery, reversibility with a two-fold reduction in cross-sensitivity compared to state of the art, and humidity-independent sensing characteristics.

M3P.038 FABRICATION OF PSEUDO-PALLADIUM NANOSTRUCTURES AND ITS APPLICATION TO HYDROGEN GAS SENSOR

Sanghoon Kim and Kwang-Seok Yun
Sogang University, KOREA

In this work, we implemented the Pd nanostructures by simply depositing Pd thin film on the hydrothermally grown $NiCO_2O_4$ nano-needles. In this way, fast response time and high sensitivity can be obtained because the hydrogen gas can be easily absorbed into the thin Pd layer resulting in the fast and steep change of the conductance.

M3P.039 GAS IONIZATION PHENOMENA AT NANOWIRE ELECTRODES

Gerhard Müller[1], J. Daniel Prades[2], Angelika Hackner[3], Andrea Ponzoni[4], Elisabetta Comini[5], and Giorgio Sberveglieri[5]
[1]Munich University of Applied Sciences, GERMANY, [2]Universitat de Barcelona, SPAIN, [3]AIRBUS Central R&T, GERMANY, [4]CNR-INO, ITALY, and [5]University of Brescia, ITALY

We have systematically investigated miniaturized versions of surface ionization gas detectors regarding their potential of detecting and distinguishing low-ionization-energy analytes from high-ionization-energy backgrounds. We present the first systematic framework to understand these devices; the main conclusion being that performance of such sensors depends not only on electrode materials but also, and specially, on the geometric shape and the architecture of the ion-emitting electrode.

M3P.040 HALF-PIPE PALLADIUM NANOTUBE NETWORK HYDROGEN SENSOR BASED ON ELECTROSPUN NANOFIBER SCAFFOLDS

Minkyu Cho, Jianxiong Zhu, Kyungnam Kang, and Inkyu Park
Korea Advanced Institute of Science and Technology (KAIST), KOREA

Half-pipe shaped palladium (Pd) nanotubes using nanofiber templates as hydrogen (H2) sensor was reported for the first time. The realization of Pd nanostructure based on electrospun nanofibers offers a facile and cost effective way to fabricate high performance H2 sensor. As a result, for 4nm thick half-pipe Pd nanotubes exhibited a high response (2.1%) to H2 gas with 21s of response time.

M3P.041 IN-SITU TRANSMISSION ELECTRON MICROSCOPY COUPLED WITH RESONANT MICROCANTILEVER FOR COMPREHENSIVE EVALUATING SULFURIZATION PERFORMANCE OF ZINC OXIDE NANOWIRES

Xueqing Wang, Pengcheng Xu, Haitao Yu, and Xinxin Li
Chinese Academy of Sciences (CAS), CHINA

We develop a new technique with in-situ TEM and resonant microcantilever to comprehensively evaluate sulfurization performance of ZnO NWs with two different diameters. The thermodynamic interaction between ZnO and SO_2 is quantitatively evaluated by resonant cantilever and the sulfurization process of ZnO NWs is observed by in-situ TEM. According to our results, ZnO NWs with 100 nm diameter is suitable for SO_2 capture, while the 500 nm diameter sample shows potentials on SO_2 sensing.

M3P.042 LUMPED ELEMENT MODEL FOR CMUTS-BASED BIOCHEMICAL RESONANT SENSOR

Yihe Zhao[1], Libo Zhao[1], Zhikang Li[1], Jie Li[1], Tingzhong Xu[1], Shuaishuai Guo[1], Zichen Liu[1], Guoxi Luo[1], Jiuhong Wang[1], Jing Li[3], Xiangyang Zhou[4], Hongyan Wang[5], Yongshun Wu[5], Yulong Zhao[1], and Zhuangde Jiang[1]
[1]Xi'an Jiaotong University, CHINA, [2]University of California, Los Angeles, USA, [3]Xiamen University, CHINA, [4]Beihang University, CHINA, and [5]Shaanxi Institute of Metrology Science, CHINA

The lumped element models (LEM) for chemical resonant sensor based on the capacitive micromachined ultrasonic transducers (CMUTs) were demonstrated and analyzed with different DC voltages. We fabricated CMUTs chip by the direct bonding process, functionalized with electrospinning technology. The modified BvD model can be attempted to illustrate features of the quality factor for both mechanical impedance and phase properties under different DC voltages.

M3P.043 AU-PD@CO3O4: A PROMISING MATERIAL FOR NEW GENERATION PELLISTOR WITH LOW WORKING TEMPERATURE

Xuemeng Lyu[1], Haitao Gao[1], Patrick Diehle[2], Frank Altmann[3], Karina R. Tarantik[2], Katrin Schmitt[1], and Jürgen Wöllenstein[1]
[1]University of Freiburg, GERMANY, [2]Fraunhofer IPM, GERMANY, and [3]Fraunhofer IMWS, GERMANY

In this contribution we present our research results on mesoporous Au-Pd@Co3O4, which can be used as pellistor material with significantly reduced working temperature (~ 300°C), allowing to avoid catalytic poisoning at high temperature for conventional pellistors. This development can be anticipated as the new concept to design robust pellistor gas sensors with a low power consumption. In addition, the lower operation temperature yields an improvement in output stability.

M3P.044 MULTIMODAL MICROFLUIDIC BIOSENSOR WITH INTERDIGITATED ELECTRODES (IDE) AND MICROELECTRODE ARRAY (MEA) FOR BACTERIAL DETECTION AND IDENTIFICATION

Avra Kundu[1], Tariq Ausaf[1], Parthiban Rajasekaran[2], and Swaminathan Rajaraman[1]
[1]Univeristy of Central Florida, USA and [2]Bio-techne Corporation, USA

We demonstrate the integration of multiple sensing modalities onto a microfluidic platform to enable acquisition of data from bacterial cells allowing for rapid detection and identification. The microfluidic biosensor consists of Interdigitated Electrodes and a Microelectrode Array for impedance and electrophysiological measurements. The device has been fabricated using makerspace and standard microfabrication technologies resulting in rapid, design-to-device manufacturing.

M3P.045 ODOR TRACE VISUALIZATION BY MOBILE ROBOT EQUIPPED WITH TWO-DIMENSIONAL LSPR GAS SENSOR

Zhongyuan Yang, Takaaki Soeda, Fumihiro Sassa, and Kenshi Hayashi
Kyushu University, JAPAN

This paper presents a Localized Surface Plasmon Resonance (LSPR) based high speed gas sensor module for gas sensing applications, including visualization of invisible odor trail. Innovative claims include: (1) the use of a double layer film with Au/Ag nanoparticles for gas detection; (2) high speed response characteristic; and (3) visualization of odor trail pattern with high spatial resolution.

M3P.046 PARYLENE-COATED PIEZOELECTRICALLY-ACTUATED SILICON DISC RESONATORS FOR LIQUID-PHASE SENSING

Hakhamanesh Mansoorzare, Sina Moradian, and Reza Abdolvand
University of Central Florida, USA

The backside and the surrounding trenches of a thin-film piezoelectric-on-silicon disc resonator are coated with Parylene to form a biocompatible insulation layer that enables liquid-phase operation of the resonator while marginally affecting its performance. By doing so, the effect of viscous damping on different resonance modes is investigated and a contour-mode is identified which exhibits the least drop in the quality factor (~70% decrease to a record Q of 320) when operated in water.

M3P.047 PIEZORESISTIVE MICROCANTILEVERS 3D-PATTERNED USING ZNO-NANORODS@SILICON-NANOPILLARS FOR ROOM-TEMPERATURE ETHANOL DETECTION

Jiushuai Xu[1], Andi Setiono[1], Maik Bertke[1], Klaas Strempel[1], Nicolai Markiewicz[1,2], Angelika Schmidt[1], Andreas Waag[1], Joan Daniel Prades[2], and Erwin Peiner[1]
[1]Technische Universität Braunschweig, GERMANY amd [2]University of Barcelona, SPAIN

This paper reports a self-actuating/sensing gravimetric ethanol sensor, based on 3D ZnO-Nanorods@Si-Nanopillars which, for the first time, are selectively fabricated on a piezoresistive silicon microcantilever (MC). This novel sensor was found to be highly sensitive to ethanol at room-temperature, with a sensitivity of hundreds times higher than that of a ZnO-nanofilm-covered MC. Fast response and recovery time were determined to be 6.1 s and 5.5 s, respectively.

M3P.048 SCALABLE ULTRA-LOW POWER CHEMICAL SENSING WITH METAL-ORGANIC FRAMEWORKS

David W. Gardner, Xiang Gao, Hossain M. Fahad, An-Ting Yang, Sam He, Ali Javey, Carlo Carraro, and Roya Maboudian
University of California, Berkeley, USA

We leverage the selectivity of metal-organic frameworks (MOFs) for gas sensing on a scalable, ultra-low power platform for chemical sensing. Our platform is based on a chemical-sensitive field-effect transistor. The sensing mechanism is based on the work function shift of the MOF sensing material. The MOF "HKUST-1" is used as a humidity sensor and the MOF "ZIF-8" is used as a selective nitrous oxide sensor that recovers without a microheater.

M3P.049 SLIVER-NANOPARTICLE ENHANCED PVA THIN-FILM COLORIMETRIC HUMIDITY SENSOR

Yangxi Zhang, Ouyang Xia, Kwun Hei Ho, Zengtian Liang, Dangyuan Lei, A.Ping Zhang, and Hwa-Yaw Tam
Hong Kong Polytechnic University, HONG KONG

We present a fast-response colorimetric humidity sensor based on silver-nanoparticle (AgNP) enhanced polyvinyl alcohol (PVA) thin-film interferometer. The AgNPs are printed on titanium dioxide (TiO_2) via precision photoreduction. The PVA-AgNP-TiO_2 structure displays more brilliant and abundant colors in colorimetric sensing. The colorimetric sensor can rapidly respond to humidity change with 87 ms rise time, and shows great potential for breath analysis and smartphone camera-based biochips.

M3P.050 TWO-CHIP WIRELESS H_2S GAS SENSOR SYSTEM REQUIRING ZERO ADDITIONAL ELECTRONIC COMPONENTS

David C. Burnett, Hossain M. Fahad, Lydia Lee, Filip Maksimovic, Brad Wheeler, Osama Khan, Ali Javey, and Kristofer S.J. Pister
University of California, Berkeley, USA

We describe a wireless hydrogen sulfide (H2S) gas sensor system comprised of two integrated circuits: a chemically-sensitive field effect transistor (CS-FET) sensor and a single-chip micro-mote (SCμM). The sensor IC is a bulk transistor functionalized to respond to H2S. The SCμM IC uses an ARM Cortex M0 to digitize sensor voltage via an ADC and transmit data through a 2.4GHz FSK transmitter based on an ultra-small, crystal-free, free-running ring oscillator.

M3P.051 ULTRASENSITIVE AND SELECTIVE MERCURY(II) ION DETECTION WITH A GLASS NANOPORE

Songyue Chen, Yongliang Tang, Kan Zhan, Hepeng Dong, Hong Chen, and Xu Hou
Xiamen University, CHINA

A surface charge modulation-based mercury(II) ion detection with a glass nanopore is presented. The DNA adaptors functionalized nanopore is selective to Hg2+, with a detection limit down to 0.1 nmol/L, which is far below the drinking water standard. The concentration of Hg2+ in solution is measured through characterizing the surface charge changing of nanopore inner wall, and analyzed by the rectification ratio of the current-voltage curve.

T3P.028 A 3D PRINTED ETHANOL SENSOR USING CONFORMALLY-COATED CONDUCTIVE POLYMER ELECTRODES

Jacqueline Elwood and Liwei Lin
University of California, Berkeley, USA

This work demonstrates conformal coating of carbon nanotube-doped poly(3,4-ethyelenedioxythiophene) polystyrene sulfonate electrodes onto PolyJet 3D printed structures to enable the fabrication of in-channel 3D electrodes for sensing applications. The electrodes are functionalized via electropolymerization of polyaniline to demonstrate a 3D printed ethanol sensor, opening up a new class of 3D printed sensing systems based on the conformal coating of conductive sensing materials.

T3P.029 A LOW-COST ION SELECTIVE NITRATE SENSOR BASED ON SELF-ASSEMBLED GRAPHENE MICROELECTRODE ARRAYS

Li Wang[1], Jungyoon Kim[2], and Tianhong Cui[2]
[1]Beijing Institute of Astronautical Systems Engineering, CHINA and [2]University of Minnesota, USA

We develop a novel micro sensor which used self-assembled graphene microelectrode arrays to selectively detect nitrate solutions. Graphene microelectrode arrays were utilized to sensitively detect the change of ion density. An ion selective ionophore film was deposited upon graphene surface to make the sensor's selectively sensitive for nitrate ions. As a result, the sensor demonstrated high sensitivity and reproducibility for nitrate ions.

T3P.030 A SELF-POWERED UV PHOTODETECTOR USING FACE-TO-FACE ZINC OXIDE NANOROD ARRAYS

Changsong Chen[1], Jiang Chen[1], Baofa Hu[1], Xueqin Lv[1], Haisheng San[1], and Werner Hofmann[2]
[1]Xiamen University, CHINA and [2]Technical University of Berlin, GERMANY

We report a self-powered ultraviolet photodetector utilizing two sets of free-standing ZnO nanorod arrays (ZNRAs) to assemble as a face-to-face nanohybrid structure. In comparison with the photodetectors based on single-face ZNRAs, the face-to-face ZNRAs-based photodetector exhibits "1+1>2"enhancements in photoelectric conversion. The device shows a high photosensitivity of 2.45 mA/W and on/off current ratio of 6.4_10^5 under a UV irradiation of 3.06 μW/cm^2 with 0 V external bias.

T3P.031 A SOLIDLY MOUNTED RESONATOR WITH CMOS-FABRICATED ACOUSTIC MIRROR FOR LOW-COST AIR QUALITY MONITORING

Farah H. Villa-Lopez[1], Marina Cole[1], Enrique Iborra[2], Mario De-Miguel Ramos[3], and Julian W. Gardner[1]
[1]University of Warwick, UK, [2]Universidad Politécnica de Madrid, SPAIN, and [3]Sorex Sensors Ltd., UK

This work presents a novel Solidly Mounted Resonator (SMR) device for use in a portable and low-cost air quality monitor. In this novel SMR structure thicknesses and materials of the acoustic mirror layers are entirely defined and fabricated by the selected CMOS process. This will enable the device to be monolithically integrated and fabricated in high volume with reduced post-processing steps.

T3P.032 AMMONIA CROSS-SENSITIVITY ELIMINATION METHOD OF NO_X SENSOR FOR UREA-SCR (SELECTIVE CATALYTIC REDUCTION) SYSTEM

Kyongtae Kim[1], Tae-Hoon Lee[1], Dong-Hyun Kang[2], Hong-Beom Kwon[1], Sang-Myun Lee[1], Seong-Jae Yoo[1], Ui-Seon Hong[1], and Yong-Jun Kim[1]
[1]Yonsei University, KOREA and [2]Korea Institute of Science and Technology, KOREA

We report an ammonia cross-sensitivity elimination filter for SCR systems. Since the NOX sensors are cross-sensitive to NH3, a reading of NOX sensor could not be accurate. The filter can be applied to any kinds of NOX sensors and effectively remove the cross-sensitivity. The single gas and mixed exhaust gases tests are conducted and the results show the evident removal of NH3 by the filters in both single gas and mixed gases experiments.

T3P.033 AN INKJET PRINTED ZNO BASED GAS SENSOR ON A FLEXIBLE HIGH TEMPERATURE SUBSTRATE FOR NO_2 SENSING

Marcel Knoll[1], Christina Offenzeller[1], Bernhard Jakoby[1], Pavel Kulha[2], Alexandr Laposa[2], and Wolfgang Hilber[1]
[1]Johannes Kepler University Linz, AUSTRIA and [2]Czech Technical University Prague, CZECH REPUBLIC

In this work we demonstrate the realization of a simple and low cost NO_2 gas sensor on a flexible polymer substrate. The sensor is fabricated using inkjet printing and hydrothermal growth. The sensitive layer is grown without a seeding layer directly on the substrate. Furthermore the operating temperature is intrinsically achieved with an inkjet printed heater, which is located on the backside of the sensor.

T3P.034 AQUEOUS MEDIA ELECTROSTATIC MEMS SENSORS

Majed Al-Ghamdi[1], Resul Saritas[2], Katherine Stewart[3], Alison Scott[2], Mahmoud Khater[4], Ayman Alneamy[2], Ahmad Abdel-Aziz[2], Hamidreza Nafissi[2], Eihab Abdel-Rahman[2], and Alexander Penlidis[2]
[1]King Abdulaziz City for Science and Technology, SAUDI ARABIA, [2]University of Waterloo, CANADA, [3]Troy University, USA, and [4]King Fahd University of Petroleum and Minerals, SAUDI ARABIA

We report a novel electrostatic MEMS sensor to detect solutes in aqueous media. The sensor is equipped with a polymeric sensing material to sorb mercury acetate dissolved in water. Shift in the resonance frequency is used to detect variations in added-mass as the concentration of mercury in water varies. The sensor was excited electrostatically, the response was measured capacitively and 100 ppm solution of mercury acetate in deionized water was utilized to demonstrate the sensor functionality.

T3P.035 CONTROL OF SURFACE POTENTIAL IN WO_3 GAS SENSORS USING UV LIGHT

Lukasz Kowalski[1], Eric Navarrete[2], Eduard Llobet[2], and Manuel Dominguez-Pumar[1]
[1]Universitat Politecnica de Catalunya, SPAIN and [2]Universitat Rovira i Virgili, SPAIN

We introduce the first control of surface potential (SP) in MOX gas sensors using UV light (365nm). The control is based on sigma-delta modulation implementing a sliding mode control on the SP of the sensor. Measurements are presented using a sensor made of WO3 nanowires under mild heating at 125ºC. Without control, the sensor shows no response to ethanol. Under control, the detection limit is below 2 ppm with a response time below 5 minutes. For NO_2, the response time is reduced by a factor 10.

T3P.036 DEEP ELECTRODE AND PARYLENE E-BASED CAPACITIVE VOC DETECTOR FOR MICRO GAS CHROMATOGRAPH APPLICATION

Cheng-Han Yeh[1], Xiangyu Zhao[2], Yutao Qin[2], Yogesh B. Gianchandani[2], Yuji Suzuki[1], and Kenichi Morimoto[1]
[1]University of Tokyo, JAPAN and [2]University of Michigan, USA

This paper presents a high-sensitivity capacitive volatile organic compound (VOC) detector with parylene E-coated high-aspect-ratio deep electrodes. In steady-state evaluation, the sensitivity of the present detector is confirmed to be enhanced by 50 times over that of the planar type. In gas chromatograph (GC) experiments, the present detector is demonstrated to capture well-resolved peaks of VOC mixtures, validating its use as a GC detector with enhanced sensitivity and limit-of-detection.

T3P.037 DROPLET RAPID-ANALYSIS METHOD OF METAL-SALT SOLUTION BASED ON TRIBOELECTRIC EFFECT

Zhaohui Wu, Jingfu Bao, Yi Zhang, Yinglan Chen, and Xiaosheng Zhang
University of Electronic Science and Technology of China, CHINA

We fabricated a novel compact sensor by printed interdigital electrodes and PTFE. Serving as functional material, PTFE and liquid droplet construct the triboelectric pair to generate electrons, while interdigital electrodes collect electrons due to the electrostatic induction. Therefore, according to the quantitative relation between the electric output signal and the situation of compound droplet, the molarity, volume and type of measured droplet were calculated.

T3P.038 FET BASED HEAVY METAL ION SENSOR TO DETECT MERCURY ION FROM WASTE WATER

Shin-Li Wang, Revathi Sukesan, Indu Sarangadharan, and Yu-Lin Wang
National Tsing Hua University, TAIWAN

A portable measurement system is used in this research. Our sensor has a short response time of 15 minutes, and the operation method is easy and convenient, suitable for home-care, as opposed to laboratory standard equipment like ICP-MS. This ion selective sensor has high sensitivity which is beyond ideal Nernst sensitivity, and a comparable detection limit with ICP-MS. This ISM-FET sensor can directly detect mercury ion from waste water which is from factory without any pre-treatment.

T3P.039 GAS VISUALIZATION WITH PHOTO-INDUCED 2D PIXEL PATTERNED AU/AG CORE-SHELL LSPR IMAGING DEVICE BY MASK-LESS EXPOSURE SYSTEM

Takaai Soeda, Zhongyuan Yang, Fumihiro Sassa, and Kenshi Hayashi
Kyushu University, JAPAN

We presents fabrication of pixelated Localized Surface Plasmon Resonance (LSPR) gas imaging sensor with different gas adsorption characteristic sensor pixel by photo-induced growth of metals (Au and Ag). Formation of pixel pattern Au/Ag core-shell LSPR nano structure by photo-induced growth by mask-less exposure system using commercial video projector and identification of gas species of the change in transmitted light intensity of pixel by LSPR were confirmed.

T3P.040 HIGHLY SENSITIVE AND LONG-TERM STABLE HYDROGEN SENSOR FOR REAL-TIME TRACING OF DISSOLVED HYDROGEN IN TRANSFORMER-INSULATING OIL

Vijay V. Kondalkar, Mun Hwan Lee, and Keekeun Lee
Ajou University, KOREA

The ambient temperature variation and Joule heating effects interference are a great obstacle for real-time dissolved hydrogen gas analysis (DHGA). We fabricated a sensor for DHGA using a Wheatstone bridge with two sensors in a single system and configurations were imported to eliminate any environmental interference factors in oil. The fabricated sensor showed an excellent response, good repeatability, and long-term stability in oil compared to state of the art.

T3P.041 IMPROVED PEFORMANCE OF MICRO-PRECONCENTRATOR USING SILICON NANOWIRES AS A SURFACE TEMPLATE

Bin Zhao, Fei Feng, Xueli Yang, Fan Luo, Haimei Zhou, and Xinxin Li
Chinese Academy of Sciences (CAS), CHINA

In this paper, a nano structure with high specific surface area was used as a surface template to improve the enrichment ability of micro-preconcentrator (μPC). The μPC was fabricated based on MEMS technology. The enrichment ratio of butyl acetate of the μPC with the nano structure was as high as 193.8, which has a 188% enhancement.

T3P.042 LOW COST NITRATE SENSOR FOR AGRICULTURAL APPLICATIONS

Van Anh T. Dam and Marcel A.G. Zevenbergen
IMEC, THE NETHERLANDS

This work presents a flexible miniaturized sensor for quick nitrate detection for agricultural applications. The sensor was fabricated on a polyethylene terephthalate (PET) foil by using techniques which can enable large scale production to reduce manufacturing costs. The flexible sensor showed a good nitrate sensitivity in a concentration range, which is suitable for soil nutrient analysis.

T3P.043 MEMS BASED PARTICLE SIZE ANALYZER USING ELECTROSTATIC MEASURING TECHNIQUES

Sang-Myun Lee[1], Hong-Lae Kim[2], Hong-Beom Kwon[1], Kyongtae Kim[1], Seong-Jae Yoo[1], Ui-Seon Hong[1], Jungho Hwang[1], and Yong-Jun Kim[1]

[1]Yonsei University, KOREA and [2]OmniSense, KOREA

This paper reports a MEMS based particle size analyzer using electrostatic measuring techniques. The MEMS based particle analyzer is able to classify particles of same diameter by using electrical mobility and measure particle size distribution in the size range of 50 to 300 nm. The performance of the proposed system was evaluated through measurements of particle size distribution and compared with commercial high precision instruments.

T3P.044 MONOLITHIC INTEGRATED CMOS-MEMS FLUORESCENCE QUENCHING GAS SENSOR AND RESISTIVE TEMPERATURE DETECTOR (RTD) FOR TEMPERATURE COMPENSATION

Ya-Chu Lee[1], Shyh-Wei Cheng[1,2], and Weileun Fang[1]

[1]National Tsing Hua University, TAIWAN and [2]Taiwan Semiconductor Manufacturing Company, TAIWAN

This study demonstrates the vertical integrated environment sensor with a fluorescence quenching based gas sensor and RTD using the TSMC CMOS process. Features of this study are integration of photo-sensors, thermal-isolation structure, temperature, and optical based gas-sensing films using CMOS and polymer dispensing technologies; multiple optical sensors equipped with thermal compensation unit are monolithically integrated and heterogeneous integration with LED can reduce the size of sensor.

T3P.045 MULTIPARAMETRIC, SPATIALLY RESOLVED DETECTION OF H_2O_2 AND O_2 WITH ELECTROCHEMICAL MICROSENSOR ARRAY IN SYNTHESIS MEMBRANE MICROREACTORS

Sebastian Urban[1], Jochen Kieninger[1], Benedikt J. Deschner[2], Manfred Kraut[2], Roland Dittmeyer[2], Gerald A. Urban[1] and Andreas Weltin[1]

[1]University of Freiburg, GERMANY and [2]Karlsruhe Institute of Technology (KIT), GERMANY

We present an electrochemical sensor system for the multiparametric detection of H_2O_2 and O_2 inside a direct synthesis membrane microreactor. Both are detected on the same Pt-based electrode by changing the potential in a chronoamp. protocol. The integration of the electrochemical cell in the microreactor was shown and allowed for in situ detection of the spatial gradient of the changing O_2 concentration diffusing through a membrane into the reactor, emphasizing the capabilities of our system.

T3P.046 OPTIMIZING SENSOR RESPONSE IN SUSPENDED, ULTRA LOW POWER CNT-FET NO_2 GAS SENSORS VIA BIAS TUNING

Sebastian Eberle, Cosmin Roman, and Christofer Hierold

ETH Zürich, SWITZERLAND

This work reports on optimum bias conditions for a carbon nanotube NO_2 gas sensor and novel insights on the sensing mechanism. When sweeping the source-drain bias Vsd (0.1-2.2V) and gate bias Vg (±10V) the change in conductivity upon gas exposure reaches a maximum at Vg=-10V and Vsd=0.6V, equivalent to a 70% sensitivity increase compared to a low-bias Vsd=0.1V. Contact barrier thinning by hole doping NO_2 molecules is proposed as a mechanism for response modulation with gas concentration

T3P.047 PERFORMANCE OF MOX GAS SENSORS OBTAINED BY MIXING P-TYPE AND N-TYPE METAL OXIDES FOR RELIABLE INDOOR AIR QUALITY MONITORING

Aymen Sendi[1], Pierre Fau[2], Myrtil L. Kahn[2], Katia Fajerwerg[2], Vincent Bley[3], Chabane Talhi[1], Frederic Blanc[1], and Philippe Menini[1],

[1]LAAS-CNRS, FRANCE, [2]LCC-CNRS, FRANCE, and [3]LAPLACE, FRANCE

In this work, we study the effect of n-p heterojunctions in metal oxides (MOX) gas sensors, and particularly on their gas sensitivity and relative humidity dependence for indoor air quality applications. This effect depends on the relative proportion of MOX in the mixture. This study was achieved in order to build a MOX gas sensor that overcomes the effects of humidity variations and to improve the overall sensitivity of MOS gas sensors.

T3P.048 RARE-EARTH BASED CHEMORESISTIVE CO_2 SENSORS

Takuya Suzuki[1,2], Andre Sackmann[1], Alexandru Oprea[1], Udo Weimar[1], and Nicolae Barsan[1]

[1]University of Tübingen, GERMANY and [2]Fujielectric Co. Ltd., JAPAN

We have been exploring the new CO_2 sensitive materials based on rare-earth compounds. In order to find how applicable the sensing materials are, a thorough study of the stability, the influence of humidity, the sensitivity to CO_2 up to 10,000ppm, and the selectivity was performed.

T3P.049 SERS DETECTION OF NEUROTOXIC AGENTS IN GAS PHASE USING MICROFLUIDIC CHIPS CONTAINING GOLD-MESOPOROUS SILICA AS PLASMONIC-SORBENT

Marta Lafuente[1], Fernando Almazan[1], Eduardo Bernad[1], Miguel A. Urbiztondo[1,2], Jesus Santamaria[1,3], Reyes Mallada[1,3], and Maria P. Pina[1,3]

[1]University of Zaragoza, SPAIN, [2]Centro Universitario de la Defensa (CUD), Academia General Militar, SPAIN and [3]Networking Research Center of Bioengineering, Biomaterials and Biomedicine (CIBER-BNN), SPAIN

In this work, we develop microfluidic Surface Enhanced Raman Spectroscopy (SERS) devices for trace recognition of neurotoxic agents. The microfabricated devices enable both the in-situ adsorption and identification of target molecules thanks to the deployment of plasmonic sorbents based on Au decorated mesoporous silica. Such microdevices exhibit high sorption efficiency towards the gas phase and remarkable SERS performance for reliable detection.

T3P.050 SUB 0.01pH RESOLUTION EXTENDED GATE TYPE pH IMAGE SENSOR WITH CHARGE ACCUMULATION FUNCTION

Yoshitaka Arimi[1], Sakamoto Kotaro[1], You-Na Lee[1], Yasuyuki Kimura[1], Toshiki Wakamori[2], Hiroo Yamamoto[2], Tatsuya Iwata[1], Toshihiko Noda[1], Kazuhiro Takahashi[1], Seiichiro Mizuno[2], and Kazuaki Sawada[1]
[1]Toyohashi University of Technology, JAPAN and [2]Hamamatsu Photonics, JAPAN

We developed a new extended gate structure pH image sensor with a pH resolution that exceeded 0.25 as a state-of-the-art bio image sensor. Improvement in pH resolution is realized by designing a pixel structure with accumulation function added to the conventional charge transfer type pH sensor. The image sensor with 256_256 pixel was evaluated to achieve the pH resolution exceeding 0.01 in 5 pixel average.

T3P.051 ULTRA LOW POWER MASS-PRODUCIBLE GAS SENSOR BASED ON EFFICIENT SELF-HEATED GaN NANOPILLARS

Nicolai Markiewicz[1], Olga Casals[2], Muhammad Fahlesa Fatahilah[1], Jiushuai Xu[1], Angelika Schmidt[1], Hutomo Suryo Wasisto[1], Erwin Peiner[1], Andreas Waag[1], and Joan Daniel Prades[2]
[1]Technische Universität Braunschweig, GERMANY and [2]Universitat de Barcelona, SPAIN

We presents a fully top-down method to produce ordered arrays of high surface-to-volume elements for gas sensing applications. Specifically, these will be used as highly integrated heating elements for conductometric gas sensing in self-heating operation. Overall, this is the first work reporting efficient self-heating in a system that has been produced at a wafer scale, using conventional microelectronic processing.

T3P.052 ZEOLITIC IMIDAZOLATE FRAMEWORK MODIFIED FILM BULK ACOUSTIC RESONATOR FOR HIGHLY SENSITIVE AND SELECTIVE ALCOHOL VAPORS DETECTION

Zhipeng Hui[1], Xu Yan[2], Hemi Qu[2], Wei Pang[2], and Xuexin Duan[2]
[1]China Marine Development and Research Center, CHINA and [2]Tianjin University, CHINA

We developed a novel film bulk acoustic resonator (FBAR) gas sensor based on zeolitic imidazolate framework-8 (ZIF-8) to detect alcohols vapor under ambient condition. The integration of micron-sized device and nanoscale porous material realizes the advantage of miniature device sizes, compatibility with metal oxide semiconductor (CMOS) technology as well as high sensitivity.

Wednesday - Chemical and Environmental Sensors and Microsystems

W3P.028 A HIGH-PERFORMANCE SELF-POWERED UV PHOTODETECTOR BASED ON SELF-DOPING TiO_2 NANOTUBE ARRAYS

Jiang Chen[1], Baofa Hu[1], Changsong Chen[1], Xueqin Lv[1], Haisheng San[1], and Werner Hofmann[2]
[1]Xiamen University, CHINA and [2]Technical University of Berlin Country, GERMANY

In this paper, we present a self-powered ultraviolet (UV) photodetector using electrochemical micro-porous channel arrays based on black TiO_2 nanotube arrays (BTNAs) and polysulfide (S2-/Sx2-) electrolyte. By self-doping oxygen vacancies and Ti3+ defects in TNAs, carrier transport and multiple exciton generation are effectively enhanced. The self-powered UV photodetector demonstrate a high photoresponsivity of ~30 mAW-1 and a high-speed response of ~4 ms in rise and decay time.

W3P.029 A METAL-OXIDE GAS SENSOR BASED ON AN AEROSOL JET PRINTING TECHNOLOGY FEATURING A ONE SECOND RESPONSE TIME

Yu-Cheng Cho[1], Mohannad Y. Elsayed[2], and Mourad N. El-Gamal[1]
[1]McGill University, CANADA and [2]MEMS-Vision International Inc., CANADA

We design and fabricate metal-oxide (MOX) gas sensors, utilizing aerosol jet printing technology, combined with microhotplates fabricated through a process based on the industrial PolyMUMPs technology complemented by in-house post-processing steps. The proposed process greatly reduces the fabrication complexity and can achieve homogeneous sensing films with sub-micron thicknesses. Measurement results show that the MOX sensors exhibit good sensitivity and feature an ultra-fast response time.

W3P.030 AN ALN RESONANT MICROCANTILEVER HUMIDITY SENSOR BY ACTIVATING SPECIFIC SETS OF TOP ELECTRODES BASED ON GRAPHENE OXIDE

Dongsheng Li, Xianhao Le, Jintao Pang, and Jin Xie
Zhejing University, CHINA

This paper presents an AlN microcantilever humidity sensor based on graphene oxide (GO). The top electrode is divided into different groups and we improve the quality factor and signal strength of particular mode by activating specific sets of top electrodes. The sensitivity is increased to ~1kHz/10%RH when the relative humidity is greater than 80%RH.

W3P.031 AN INTEGRATED MINIATURE CONDUCTIVITY AND TEMPERATURE SENSOR CHIP WITH OPEN-CELL ANNULAR ELECTRODE

Bojie Zhang, Qi Cheng, Zesen Bai, Qiancheng Zhao, and Zhenchuan Yang
Peking University, CHINA

We develop a novel open-cell four annular electrodes conductivity sensor with in-situ temperature measurement.The whole system including sensor chip and optimized support circuit can achieve accuracy that 0.01mS/cm with 0.002mS/cm resolution and 0.01°C with 0.0004°C resolution respectively by eliminating proximity effects. The size of sensor chip is very small which is just 5mm * 8mm.

W3P.032 COLORIMETRIC SENSOR SYSTEM FOR THE DETECTION OF LOW CO-CONCENTRATIONS IN REAL FIRE TESTS

Carolin Pannek[1], Christian Weber[1,3], Thomas Vetter[1], Roland Pohle[2], Laura Engel[1], André Eberhardt[1], Karina R. Tarantik[1], and Jürgen Wöllenstein[1,3]
[1]Fraunhofer IPM, GERMANY, [2]Siemens, GERMANY and [3]University of Freiburg, IMTEK, GERMANY

We developed a colorimetric sensor system for the detection of carbon monoxide (CO) in low ppm concentrations. As it is low power and low-cost, the sensor enables the integration into a commercial fire detector. Our here presented novelty is the improved sensor development using screen printing techniques, the higher integration into a sensor system and its performance in real-fire tests.

W3P.033 CoPP-FUNCTIONALIZED TIO_2 NANOPARTICLES FOR HIGHLY SENSITIVE AND RELIABLE VOC DETECTION

Yunsung Kang, Kwanhun Kim, Byeonghwa Cho, Yeunjun Kwak, and Jongbaeg Kim
Yonsei University, KOREA

This paper reports the chemiresistive sensor for volatile organic compounds (VOCs) based on titanium dioxide (TiO_2) nanoparticles functionalized with cobalt-porphyrin (CoPP) for the first time. The proposed VOCs sensor with a micro-heater presents both the high sensitivity and reliability with low-power consumption, which is essential for the use in mobile devices.

W3P.034 DENSITY MEASUREMENT PERFORMANCE IN FLOWING LIQUID USING MICROCANTILEVER-BASED RESONATORS UNDER BENDING AND TORSION VIBRATIONS

Linya Huang[1], Libo Zhao[1], Yingjie Hu[1], Hongyan Wang[2], Dejiang Lu[1], Xudong Fang[1], Guoxi Luo[1], Chenying Wang[1], Ping Yang[1], Weixuan Jing[1], Yulong Zhao[1], and Zhuangde Jiang[1]
[1]Xi'an Jiaotong University, CHINA and [2]Shaanxi Institute of Metrology Science, CHINA

We have analyzed the influence of flowing velocity of liquid on the measuring performance of microcantilever-based resonator in density determination. Experiments are carried out based on different dimensions and different operation modes of the microcantilevers. This research provides approaches to reduce flowing damping and guarantee the density measuring performance of microcantilever-based resonator in flowing liquid.

W3P.035 FABRICATION OF A STRIPE-GATE TYPE PH SENSOR FOR INHIBITION OF DRIFT IN PH MEASUREMENT FOR LONG-TERM SOIL MONITORING

Masato Futagawa, Keisuke Uemura, Ryuta Oishi, Satoshi Ota, and Harutoyo Hirano
Shizuoka University, JAPAN

An ISFET type pH sensor with stripe gate electrodes to inhibit the drift was fabricated for long-term pH measurement. The line and space patterns of stripe gate electrodes were fabricated under the pH sensing membrane in a channel area of the FET. The gate electrodes were applied voltage to suppress the diffusions of the anions from the object solution in the sensing membrane. We could confirmed the inhibition of the drift using the gate electrodes.

W3P.036 FILM MORPHOLOGY EFFECT ON VOC SENSOR PERFORMANCE FABRICATED BY DROP-ON-DEMAND INKJET-PRINTING

Mohammad Mahdi Kiaee, Thomas Maeder, and Jürgen Brugger
École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND

We present an inkjet-printed chemiresistive VOC sensor. The sensing material is composed of a composite containing polystyrene and a high structure carbon black. Printability of the composite in single and dual solvent systems has been studied, and the effect of film morphology on sensor performance has been investigated. We observed a 2-fold improved sensitivity due to the absence of coffee ring effect and superior response/recovery time by optimizing print strategy.

W3P.037 GC-QEPAS: A MEMS-ENABLED PORTABLE TRACE CHEMICAL SENSOR FOR SAFETY & SECURITY APPLICATIONS

Sandro Mengali[1], Ivan Elmi[2], Luca Masini[2], Filippo Bonafé[2], Fabrizio Tamarri[2], Michele Sanmartin[2], Roberto Viola[1], Nicola Liberatore[1], and Stefano Zampolli[2]
[1]Consorzio CREO, ITALY and [2]CNR-IMM Bologna, ITALY

In the framework of the Horizon2020 "ROCSAFE" project, we develop a portable selective sensor for trace concentrations of hazardous vapors, combining MEMS purge&trap pre-concentration and gas-chromatographic (GC) separation devices and a miniaturized quartz-enhanced photoacoustic spectroscopy (QEPAS) detector. The system enables analyses in dirty environments with response time of a few minutes. It was designed to be rugged and suitable to be deployed on unmanned robotic ground vehicles.

W3P.038 HIGH SENSITIVITY GAS SENSOR BASED ON POROUS GAN NANORODS WITH EXCELLENT HIGH-TEMPERATURE STABILITY

Mingxiang Zhang[1], Changhui Zhao[1], Huimin Gong[1], Gaoqiang Niu[1], and Fei Wang[1,2]
[1]Southern University of Science and Technology, CHINA and [2]Chinese Academy of Sciences (CAS), CHINA

We fabricated porous GaN nanorods by hydrothermal method for gas sensor application via a simple process. Gas-sensing measurements demonstrate that the porous GaN-based sensor exhibits high sensitivity and good selectivity to ethanol, which also shows a fast response/recovery time and excellent high-temperature stability at high temperature. Our study provides a promising route for the fabrication of porous GaN-based sensitive materials for high-performance gas sensors.

W3P.039 HIGHLY SENSITIVE ALN CONTOUR-MODE RESONATOR-BASED PRESSURE SENSOR FOR IN-LINE MONITORING OF CHEMICAL REACTIONS

Jingjing Zuo, Hainan Zhang, Ye Chang, Ji Liang, Wei Pang, and Xuexin Duan
Tianjin University, CHINA

We have developed, modeled and optimized a highly sensitive pressure sensor based on a microelectromechanical system (MEMS) aluminum nitride (AlN) contour-mode resonator (CMR), which is experimentally verified by measuring the pressure within a range of 0 kPa to 200 kPa. The sensors, offering enhanced linearity, achieve an improved sensitivity of 16.51 Hz/hPa, making them suitable for performing in-line monitoring of gaseous species production chemical reactions.

W3P.040 IMPROVED GAIN AND BANDWIDTH OF WATER-GATED FIELD EFFECT TRANSISTOR (WG-FET) CIRCUITS USING SOLUTIONS WITH HIGHER ION CONCENTRATION

Ozan Ertop, Bahadir Donmez, and Senol Mutlu
Bogazici University, TURKEY

We present, for the first time, the improvement of gain and bandwidth of water-gated field effect transistor (WG-FET) circuits using higher ion concentrations of NaCl solutions. The gain and bandwidth of a common source amplifier built with WG-FET depend mostly on the resistance of solution droplet and electrical double layer (EDL) capacitances. Increasing the molarity from DI-water to 20 mM increases the gain from 1.65 dB to 8.05 dB and the unity-gain frequency from 10 Hz to 1 kHz.

W3P.041 LOW-COST EXTENDED-GATE FIELD EFFECT TRANSISTOR SENSING SYSTEM BASED ON A CHANNEL STRUCTURED REFERENCE ELECTRODE

Xinran Wang, Yang Tian, Yuncong Chen, Yueyi Jiao, Md. Azahar Ali, Le Wei, and Liang Dong
Iowa State University, USA

We develop a low-cost extended-gate field effect transistor (EGFET) sensing system which, for the first time, integrates a microfluidic channel based reference electrode (μcRE) to increase potential stability for long-term measurement. The sensor could be applied to continuously monitor environmental nutrient concentration in soil and tile water.

W3P.042 MEMS MEETS ZINC-OXIDE NANOWIRES FOR REAL-TIME MONITORING OF AIR PURIFICATION: CASE OF TOBACCO SMOKE

Alaa Fathy[1], Marie Le Pivert[1], Youngjai Kim[1], Mazen Erfan[1], Yasser M. Sabry[2], Yamin Leprince-Wang[1], Tarik Bourouina[1], and Martine Gnambodoe-Capochichi[1]
[1]Université Paris-Est, FRANCE and [2]Ain-Shams University, EGYPT

Online monitoring of air purification is presented, where purification is made by photo-catalysis using ZnO nanowires, while monitoring is achieved by a MEMS-FTIR spectrometeroperating in MIR spectral range. Real-time monitoring of the purification process isdemonstrated. The experiment was conducted on toluene, acetone as well as tobacco smoke. Thewhole system appears as an efficient and cheap solution for indoor and outdoor purification andmonitoring of air.

W3P.043 MONOLITHIC INTEGRATED CMOS-MEMS MOS TYPE GAS SENSOR AND NOVEL HEATER FOR SENSITIVITY AND POWER CONSUMPTION ENHANCEMENT

Ya-Chu Lee[1], Shyh-Wei Cheng[1,2], Yu-Cheng Lin[3], and Weileun Fang[1]
[1]National Tsing Hua University, TAIWAN, [2]Taiwan Semiconductor Manufacturing Company, TAIWAN and [3]National Cheng Kung University, TAIWAN

This study designs and implements a MOS type gas sensor. The chip implemented using TSMC CMOS process and the sensing material prepared by hydrothermal synthesis method. The gas concentration is detected based on the resistance change measured by proposed sensor. Features of this study are vertical integration of heater and ZnO-SnO_2 gas-sensing films on CMOS-MEMS structure and the heater design significantly decrease power consumption and increase response of gas sensor.

W3P.044 NOVEL CONCEPT FOR ROOM TEMPERATURE NO_2 DETECTION: USING METAL OXIDES AS RESISTIVE GAS DOSIMETERS

Ricarda Wagner, Daniela Schönauer-Kamin, and Ralf Moos
University of Bayreuth, GERMANY

ZnO is investigated as gas sensor to detect ppb-level concentrations of NO2 at room temperature. The sensor operates as a dosimeter type sensor to detect directly the NO2 dose.

W3P.045 PAPER-BASED AND TIME-CONTROLLED MICROFLUIDIC CHIP FOR PESTICIDE DETECTION

Yang-Shun Wu[1], Yi-Wen Liu[1], Yun-Ju. Chuang[2], Pei-Ru Chen[2], Yi-Lin Hsu[1], and K.Y. Hung[1]
[1]Ming Chi University of Technology, TAIWAN and [2]Ming Chuan University, TAIWAN

To realize the detection of pesticide, this study developed a paper-based chip involving a 2D to 3D flow channel and automatic time delay for detecting pesticides. The time delay was controlled by different pullulan concentrations.

W3P.046 PHOTOCATALYTIC GAS SENSORS INTEGRATED ON MICRO UV-LEDS FOR EFFICIENT PHOTON ENERGY TRANSFER

Incheol Cho, Minkyu Cho and Inkyu Park
Korea Advanced Institute of Science and Technology (KAIST), KOREA

We have developed photocatalytic gas sensors integrated on μUV-LEDs for high photo-irradiation efficiency. Due to the proximity of the light source to the sensing materials, the irradiation efficiency was improved. Furthermore, absorption spectrum of the sensing nanomaterials was modulated for more efficient photon energy absorption of the gas sensing material. As a result, the sensing performance for NO_2 gas showed high sensitivity, fast response, and complete recovery in room temperature.

W3P.047 REAL-TIME OPTICAL OZONE SENSOR FOR OCCUPATIONAL EXPOSURE ASSESSMENT

Christelle Ghazaly[1,2], Marianne Guillemot[1], Blandine Castel[1], Eddy Langlois[1], Mathieu Etienne[2], and Marc Hebrant[2]
[1]Institut National de Recherche et de Sécurité (INRS), FRANCE and
[2]Laboratoire de Chimie Physique et Microbiologie pour les Matériaux et l'Environnement (LCPME), FRANCE

A cumulative, simple and inexpensive sensor using visible spectroscopy for real-time ozone detection was developed. The fabricated sensor consists of mesoporous silica thin film impregnated with methylene blue. The developed sensor can detect in real-time the one-tenth of the French occupational threshold limit value of ozone. In addition, a proposed model was used to predict the detected ozone concentrations by the developed sensor.

W3P.048 THERMO-CATALYTIC GAS SENSOR BASED ON SUSPENDED NOBLE-METAL NANOTUBES FOR H2 SENSING

Dionisio V. Del Orbe Henriquez, Incheol Cho, Kyungnam Kang, Jaeho Park, and Inkyu Park
Korea Advanced Institute of Science and Technology (KAIST), KOREA

We construct a low power thermo-catalytic gas sensor based on the local hydrothermal synthesis of high wt% Pt nanotubes (NTs), as the catalytic layer, onto a strip-type, double anchored SiO_2 beam with an embedded Resistive Temperature Detector (RTD). The reported method provides precise and selective synthesis control over small areas, resulting in high performance (due to the high catalytic activity and high thermal conductivity of the NTs) and low power (due to the small size of the device).

W3P.049 ULTRA-LONG-LIFE MINIATURE PH SENSOR WITH A SMA VALVE-ACTUATOR INTEGRATED LIQUID JUNCTION FOR RUMEN MONITORING

Shogo Higuchi, Seiichi Takamatsu, and Toshihiro Itoh
University of Tokyo, JAPAN

We develop an ultra-long-life miniature pH sensor for rumen monitoring by introducing a newly-developed Ag/AgCl reference electrode (RE) with a SMA valve-actuator integrated liquid junction. Since previous studies reports that short life time of REs is caused by outflow of internal electrolyte, we introduce valve-actuator to reduce the outflow.

W3P.050 µ-PRECONCENTRATORS USING PROTIC IMIDAZOLIUM POLYIONIC LIQUIDS FOR CHEMICAL WARFARE AGENTS SAMPLING AT TRACE LEVEL

Fernando Almazan[1], Lorien Val[1], Miguel Urbiztondo[1,2], Maria P. Pina[1,3], and Jesus Santamaria[1,3]
[1]University of Zaragoza, SPAIN, [2]Centro Universitario de la Defensa (CUD), Academia General Militar, SPAIN and
[3]Networking Research Center on Bioengineering, Biomaterials and Biomedicine (CIBER-BBN), SPAIN

We develop a simple and straightforward method for the in situ activation of microfabricated preconcentrators with ammonium based poly-ionic liquids (PIL). The capture efficiency of such microfluidic devices is demonstrated for nerve agent surrogate collection at ppmV concentration in gas phase. The equilibrium sorption capacity of PIL overcomes those reported for reference commercial sorbents.

Monday - Energy and Power MEMS

M3P.052 A HYBRIDIZED METAL-POLYDIMETHYLSILOXANE SPONGE FOR MULTIDIRECTIONAL PRESSURE ENERGY HARVESTING

Kaisi Xu[1], Ningli Zhu[2], Wei Zhang[1], and Yilong Hao[1]
[1]Peking University, CHINA and [2]Aisino Co., Ltd., CHINA

This paper presents a wire-embedded triboelectric nanogenerators (wire-TENGs) for multidirectional pressure energy harvesting. The voltage signal output has a maximum peak-to-peak value of 45 V and the current signal output has a maximum peak-to-peak value of 400 nA. And the maximum average output power of TENG reaches 0.25 µW under the external load of 100KΩ.

M3P.053 EFFECTS OF DISC-SHAPED PIEZOELECTRIC SIZE REDUCTION ON RESONANT INDUCTORLESS DC-DC CONVERTER

Benjamin Pollet[1,2], Moustapha Touhami[1,3], Ghislain Despesse[1,3], and François Costa[4,5]
[1]CEA-LETI, FRANCE, [2]SATIE, ENS Paris-Saclay, FRANCE, [3]Université Grenoble Alpes, FRANCE,
[4]Université Paris-créteil, FRANCE and [5]ESPE, Saint-Denis, FRANCE

We study the impact of disc-shaped piezoelectric dimensions on a recently presented inductorless DC-DC converter. An analytical model linking geometrical to output power and efficiency is introduced and reveals the benefits of reducing the thickness and diameter of the piezoelectric disk. Five piezoelectric discs with different dimensions are tested and compared in experimental work giving very high efficiency up to 98% and output power up to 1.7 W.

M3P.054 NON-CONTACT MULTIPLE PLUCKING METHOD FOR FREQUENCY UP CONVERSION PIEZOELECTRIC ENERGY HARVESTERS IN EXTREMELY LOW FREQUENCY APPLICATIONS

Zhewei Chen, Feiyu Zhang, Xuanzi Xu, Zhangxiong Chen, Wenming Li, Feng Li, Jiarong Han, Haowen Zhou, Kun Xu and Ling Bu
China University of Geosciences, CHINA

Non-contact multiple plucking method is presented for frequency up conversion piezoelectric cantilever to achieve peak output power of 1.8µW in extremely low frequency range of 0.01-0.1Hz. The cantilever is plucked multiple times in one cycle, so as to increase output power at low frequency. Two pairs of magnets achieve 4 times of non-contact magnetic plucking force per cycle. The proposed non-contact multiple plucking method can be further extended and scaled in micro scale energy harvesters.

M3P.055 SELF-POWERED WEARABLE MULTI-SENSING BRACELET WITH FLEXIBLE THERMOELECTRIC POWER GENERATOR

Jinfeng Yuan and Rong Zhu
Tsinghua University, CHINA

We develop a self-powered multi-sensing bracelet with integrations of flexible thermoelectric power generator (FTEG), a smart power management system, and multiple sensors, which allows simultaneously monitoring of temperature, humidity, and motion of human body that is powered by body heat at various conditions including motion and quiescence.

M3P.056 VERTICALLY INTEGRATED DOUBLE BUCKLED-BRIDGE FOR SOFTENING NONLINEAR PIEZOELECTRIC ENERGY HARVESTER

Zhiran Yi, Yingwei Tian, Xiaoxue Dong, Jingquan Liu, and Bin Yang
Shanghai Jiao Tong University, CHINA

This paper firstly reports a vertically integrated double buckled-bridge for broad bandwidth piezoelectric energy harvester based on the thinned piezoelectric thick films on flexible polymer substrate. A nonuniform distribution of the stiffness in buckled-bridge results in a broad bandwidth compared to state of the art through inducing large deformation, which attributes to a reversible nonlinear mechanism from softening to hardening nonlinear effect.

Tuesday - Energy and Power MEMS

T3P.053 A 13.56 MHZ METAMATERIAL FOR THE WIRELESS POWER TRANSMISSION ENHANCEMENT IN IMPLANTABLE BIOMEDICAL DEVICES

Kuan-Jung Chen[1], Wei-Ming Chen[2], Li-Yang Tang[1], Yu-Ting Cheng[1], Ming-Dou Ker[1], and Chung-Yu Wu[1]
[1]National Chiao Tung University, TAIWAN and [2]A-Neuron Electronic Corporation, TAIWAN

This paper presents a 13.56MHz metamaterial for wireless power transmission enhancement in implantable biomedical devices. The power transmission efficiency will increase from 46% and 39% to 51% and 46% with the metamaterial, while the transmitting and receiving antennas are placed with a 1cm distance and 1cm offset horizontal misalignment and a 1.5cm distance with an axial offset of 15°, respectively.

T3P.054 A NATURAL WIND-DRIVEN 3D-PRINTED MINIATURIZED AND FULLY ENCLOSED HYBRID NANOGENERATOR USING FLEXIBLE BLADE STRUCTURE FOR SUBWAY TUNNEL APPLICATIONS

Muhammad T. Rahman, Md. Salauddin, and Jae Y. Park
Kwangwoon University, KOREA

We have developed and experimentally validated a wind-driven hybrid nanogenerator (WH-NG) based on triboelectric nanogenerator (TENG) and electromagnetic generator (EMG) for efficiently scavenging ambient wind energy. The flexible-blades based hybridization mode TENG and multipole disc-magnets based EMG were introduced into a single rotating system to obtain a high-power output under low wind speed.

T3P.055 HIGH-FREQUENCY MICRO SUPERCAPACITORS BASED ON HIGH-ASPECT-RATIO 3D NANOPOROUS GOLD INTERDIGITAL ELECTRODES FOR ON-CHIP FILTERING

Fan Xia, Sixing Xu, Bingmeng Hu, Xinyan Jia, and Xiaohong Wang
Tsinghua University, CHINA

This paper presents a novel high-frequency on-chip micro supercapacitor (MSC) with both high capacity and superior frequency response. To augment the material loading and reduce the ionic resistance, a three-dimensional porous structure is fabricated to promote the performance. Together with the integrability and the compatibility with micro fabrication technology, it shows great advantages compared with traditional electrolytic capacitors.

T3P.056 PRINTING PAPER-LIKE PIEZOELECTRIC ENERGY HARVESTERS BASED ON NATURAL CELLULOSE NANOFIBRILS

Yangyuan Ba, Jingfu Bao, Ruiyang Song, Chenhui Zhu, and Xiaosheng Zhang
University of Electronic Science and Technology of China, CHINA

A novel paper-like PEH was developed here. The main contribution of this work can be summarized as follows. (1) Natural cellulose nanofibrils and BTO nanoparticles were successfully combined to realize piezoelectric features. (2) A printing fabrication process based on roll-coating and screen-printing were proposed, which is simple and cost-effective. (3) It was demonstrated that this energy harvester is ultra-flexible to collect omnidirectional bio-mechanical energy from human body motion.

T3P.057 STUDY ON THE APPLICABILITY OF RESONANT MODE MEMS DC/DC CONVERTERS

Benjamin Arnold, Henry Schmidt, and Jan E. Mehner
University of Technology Chemnitz, GERMANY

We present a study of the applicability of resonant Si-MEMS dc/dc converters, which do not need a separate actuator. The converter is capable of boosting the polarization voltage of capacitive MEMS devices, which is beneficial in terms of sensitivity, displacement or produced force. It is integrable next to the supplied MEMS using the same fabrication technology. A test board for the characterization of resonant dc/dc converters and a SPICE behavioral model of the device is developed.

W3P.051 A 3D MEMS IN-CHIP SOLENOID INDUCTOR OF HIGH INDUCTANCE DENSITY FOR FUTURE POWER-MEMS DEVICE

Tiantong Xu[1], Jiamian Sun[1], Hanxiao Wu[1], Haiwang Li[1], Hanqing Li[2], Jingchao Xia[1], Zhi Tao[1], and Martin A. Schmidt[2]
[1]Beihang University, CHINA and [2]Massachusetts Institute of Technology, USA

We design, fabricate and test a new type of 3D in-chip solenoid inductor. In this design, the inductor was built totally inside the silicon substrate by MEMS fabrication technology, to take the full use of the substrate thickness. This inductor will be suitable to build power MEMS devices such as the linear motor, radial flux motor, horizontal energy harvester and etc. The fabrication process can be easily compatible with IC process to add more possibilities for future microsystems.

W3P.052 BANDWIDTH ENHANCEMENT OF VIBRATIONAL ENERGY HARVESTERS BY A VOLTAGE-BOOST RECTIFIER CIRCUIT

Yukiya Tohyama[1], Hiroaki Honma[1], Noboru Ishihara[2], Hiroshi Toshiyoshi[1], and Daisuke Yamane[2,3]
[1]University of Tokyo, JAPAN and [2]Tokyo Institute of Technology, JAPAN and
[3]Japan Science and Technology Agency (JST) PRESTO, JAPAN

This paper reports a bandwidth enhancement technique using a voltage-boost rectifier (VBR) circuit for vibrational energy harvesters (VEHs). The VBR circuit rectifies and boosts small output AC voltages of VEHs (Vpp < 1 V) at low frequency (< 1 kHz) to a DC voltage of effective level for the subsequent circuitry. Experimental results confirm that the working bandwidths of a MEMS electret VBH with the VBR circuit are nearly threefold larger than those of conventional diode rectification.

W3P.053 CASCADED SMA-FILM BASED ELASTOCALORIC COOLING

Florian Bruederlin[1], Lars Bumke[2], Eckhard Quandt[2], and Manfred Kohl[1]
[1]Karlsruhe Institute of Technology (KIT), GERMANY and [2]Kiel University, GERMANY

We demonstrate a novel miniature cooling device using the combined elastocaloric effect of three cascaded TiNiCuCo films allowing to double the temperature span of a single film device (7.6 K) to 15 K. Ultra-low fatigue shape memory alloy films are arranged in series and subjected to pseudoelastic load cycles to investigate the effects of operation conditions and number of cascaded units on the cooling performance. The specific cooling power of a first-of-its kind demonstrator reaches 17 W/g.

W3P.054 DUAL-STAGE-ELECTRODE-ENHANCED EFFICIENT SSHI FOR ROTATIONAL ELECTRET ENERGY HARVESTER

Yiran Liu[1], Adrien Badel[2], Tomoya Miyoshi[1], and Yuji Suzuki[1]
[1]University of Tokyo, JAPAN and [2]Université Savoie Mont Blanc, FRANCE

We present a dual-stage electrode design for electret-based rotational energy harvester (EH) to improve efficiency of synchronized switch harvesting on inductor (SSHI) technique. With the aid of the present parallel SSHI circuit, the output power of rotational electret EH becomes 2.6 times higher than that with the conventional circuit using a resistive load.

W3P.055 ISOLATED VOLTAGE SENSOR USING RING RESONATOR FOR BATTERY POWER MANAGEMENT

Naoki Nobunaga[1], Shinya Kumagai[1], Katsuya Masuno[2], Hiroki Ishihara[2], Makoto Ishii[2], and Minoru Sasaki[1]
[1]Toyota Technological Institute, JAPAN, and [2]Yazaki Corporation, JAPAN

The electrostatic ring resonator is newly applied for measuring the voltage in a highly isolated manner. The principle is the resonant frequency shift caused by the electrical field. The ring resonator is for increasing the resonant frequency and Q. The realized values are 100kHz and 320, they are more than 5- and 2-times increase compared to the previous translation type resonator. The measurement over 380V matches with the need.

W3P.056 SELF POLED, FLEXIBLE PIEZOELECTRIC ENERGY HARVESTER BY PLACING HIGHLY CHARGED PDMS-rGO LAYER BETWEEN P(VDF-TrFE)-PMN-PT COMPOSITE SHEETS

Usman Yaqoob[1], Md Habibur Rahaman[1], Kyeong-Keun Choi[2] and Hyeon Cheol Kim[1]
[1]University of Ulsan, KOREA and [2]National Institute of Nanomaterials Technology, POSTECH, KOREA

This study investigates the role of highly charged electrostatic polydimethylsiloxane-reduced graphene oxide (PDMS-rGO) layer in achieving self-poled piezoelectric energy harvester (PEEH) using P(VDF-TrFE)-PMN-PT composite sheets. To obtain the tri-layer structure PDMS-rGO layer was sandwiched between P(VDF-TrFE)-PMN-PT composite sheets using spin coating method. It was estimated that our highly flexible, self-poled PEEH can be a potential candidate for it's used in various portable electronics.

W3P.057 TEMPERATURE DIFFERENCE MEASUREMENT ACRORSS MEMS BASED NANOGAP CREATED BY CLEAVAGE OF SILICON FOR THERMIONIC GENERATION

Masaki Shimofuri, Yoshikazu Hirai, Toshiyuki Tsuchiya, and Osamu Tabata
Kyoto University, JAPAN

For power generation using small amount of heat, thermionic generation using nanogap is considered. Thermionic generation requires a high temperature source, but it's possible to generate electricity even around room temperature by quantum effect using nanogap. Nanogap with ~100 nm distance gap and large area, parallel smooth facing surfaces was fabricated by cleaving single-crystal silicon beam by using MEMS and measured heat transport properties to evaluate the performance as a generator.

M3P.057 A NOVEL HIGH PERFORMANCE PIEZOELECTRICALLY DRIVEN MICROLENS ACTUATOR FOR MICRO-OPTICS APPLICATIONS

Ssu-Han Chen, Aron Michael, and Chee Yee Kwok
University of New South Wales, AUSTRALIA

We present a novel high performance piezoelectrically driven microlens actuator for micro-optics. The actuator exhibits large out-of-plane displacement of 228um at 22V with a low power consumption of 3.5mW. The resonance frequency of the actuator loaded with a PDMS microlens is 0.89 kHz. The high performance is achieved by using UHV E-beam Evaporated polysilicon as the device platform to manipulate the initial static deflection of the actuator to help compensate structure straining.

M3P.058 AC RELIABILITY OF INTEGRATED LOW-TEMPERATURE PVD PZT FILMS

Daniel Monteiro Diniz Reis[1], Sven Rzepka[2], and Karla Hiller[3]
[1]Robert Bosch GmbH, GERMANY, [2]Fraunhofer ENAS, GERMANY, and
[3]Technische Universität Chemnitz, GERMANY

Lead Zirconate Titanate (PZT) films are important for many applications in MEMS e.g. micro-mirrors, micro speakers, or print heads. In this work reliability of an integrated low-temperature PVD PZT film stack for the important case of unipolar AC stress over temperature and DC offset is discussed. Closing the literature gap, breakdown data with statistical relevance is presented. Comparison with results obtained under DC stress reveals that DC degradation dominates under unipolar AC load.

M3P.059 BIREFRINGENCE MODULATION OF RECONFIGURABLE METASURFACE BASED ON THERMAL BIMORPH ACTUATOR AT THE VISIBLE RANGE

Takashi Shimura and Kentaro Iwami
Tokyo University of Agriculture and Technology, JAPAN

Integration of optical metamaterial and microelectromechanical systems (MEMS) actuators have opened up a novel research field of reconfigurable metasurfaces. This paper presents a gold nanograting-based metasurface integrated with a thermal bimorph actuator for birefringence reconfiguration.

M3P.060 DEMONSTRATION OF A MEMS-MIRROR, 3D-LIDAR SYSTEM WITH LARGE APERTURE AND SCANNING ANGLE

Jürgen Hasselbach[1,2], Frank Kästner[1], Remigius Has[1], Siegwart Bogatscher[1], and Christian Rembe[2]
[1]Robert Bosch GmbH, GERMANY and [2]Clausthal University of Technology, GERMANY

Our concept of miniaturized LiDAR systems incorporates a small MEMS mirror and an optimized micro-optical array for high light-collection efficiency. This realizes constant angular resolution, robustness against front lens contamination and long measurement ranges for an eye-save LiDAR system. By simulation and experiments, we proof the avoidance of shading in the field of view and show real distance measurements, achieving optimal light distribution and collection over the field of view.

M3P.061 FABRICATION OF BIOMIMETIC ARTIFICIAL COMPOUND EYES

Boshen Zhang, Jing Hua, Yang Zhao, Jimmy Ching-Ming Chen, and Mark Ming-Cheng Cheng
Wayne State Unversity, USA

For the first time, this paper demonstrated a novel method that combines the 3D printing as well as polymer refill and surface tension to mimic the complex geometry of artificial apposition compound eyes. The compound eye camera systems have attracted a lot of attention in recent years thanks to several advantages including a wide field of view, highly sensitive to detect moving objects, and fast response time.

M3P.062 MAGNETICALLY DRIVEN ACTUATORS FOR VECTOR SCANNING MEMS MIRRORS

Shanshan Gu-Stoppel, Florian Niekiel, Marec Timmermann, Thomas Lisec and Fabian Lofink
Fraunhofer ISIT, GERMANY

This paper reports a new type of magnetic actuator with integrated NdFeB in Si. To develop the driving concept different designs and coils have been employed for evaluating the force generation and power consumption. High force of up to 0.01 N was measured by activating one single micro-magnet. Great design flexibility is given, since the force delivery of actuators can be adapted by changing quantity and volume of the micro-magnets fulfilling the requirement of vector scanning MEMS mirrors.

M3P.063 METAMATERIAL EMBEDDED OPTICAL DEVICES FOR MILLIMETER WAVE AND TERAHERTZ APPLICATIONS

Aydin Sadeqi, Hojatollah Rezaei Nejad, Rachel Owyeung, and Sameer Sonkusale
Tufts University, USA

We propose a unique metamaterial embedded geometrical optics device formed through the fusion of a frequency selective metamaterial with an optical parabolic reflector. This device combines individual properties of an optical device (parabolic mirror) and photonic device (metamaterial) in a single device. The fabricated device operates in the millimeter wave frequency range. Simulation and measurement results using terahertz continuous-wave spectrometer validate its functionality.

M3P.064 ON-CHIP PARALLEL ARCHITECTURE MEMS FTIR SPECTROMETERS ENABLING HIGH SPECTRAL RESOLUTION FOR ENVIRONMENTAL GAS ANALYSIS

Alaa Fathy[2,3], Yasser M. Sabry[1,2], Tarik Bourouina[3], and Diaa Khalil[1,2]
[1]Ain Shams University, EGYPT, [2]Si-Ware Systems, EGYPT and [3]ESIEE-Paris EST University, FRANCE

We report novel two MEMS parallel FTIR spectrometers integrated on the same chip for air quality monitoring applications. The new architecture increases the scanned optical path difference OPD of conventional MEMS spectrometer by 2x for the same actuator range leading to 1.8x improvement of wavelength resolution. Methane was measured using the new architecture, compared with the measurement of a single interferometer MEMS-FTIR and a benchtop spectrometer demonstrating the enhancement.

M3P.065 PIEZOELECTRIC SCANNING MICROMIRROR WITH LARGE SCAN ANGLE BASED ON THIN FILM ALUMINUM NITRIDE

Katja Meinel[1], Chris Stoecke[1,2], Marcel Melzer[1], Sven Zimmermann[1,2], Roman Forke[2], Karla Hiller[1,2], and Thomas Otto[1,2]
[1]*Chemnitz University of Technology, GERMANY and*
[2]*Fraunhofer Institute for Electronic Nano Systems, (ENAS) GERMANY*

In this paper micromirrors based on piezoelectric thin film aluminum nitride are presented. The microsystems with 6 mm² footprint achieve a large tilt angle by FEM-based optimization of the lever arm parameters. In resonance the micromirrors reach tilt angles up to 51.3° at 1.9 kHz and a drive voltage of less than 5 V. For higher actuation voltages up to 20 V a scan angle of 104.9° is achieved.

M3P.066 TUNABLE BROADBAND MEMS FABRY-PÉROT NEAR INFRARED FILTER BASED ON DOUBLE-MEMBRANE SILICON/AIR MIRRORS

Christoph Krämmer, Reinhold Rödel, Christian Huber, Marc Schmid, and Thomas Buck
Robert Bosch GmbH, GERMANY

We present a double-membrane Fabry-Pérot interferometer (FPI) operating in first order comprising two symmetric Si/Air Bragg mirrors operating in a spectral range from 900 to 1650 nm. The approach allows optical gap and actuation gap to be separated, enabling independent adjustment of initial transmission wavelength and maximum mirror travel range. To our best knowledge, it is the first time a FPI based on Si/Air mirrors is tuned over the full first order free spectral range.

Tuesday - Integrated Photonics and Optical MEMS

T3P.058 A COMPACT OMNIDIRECTIONAL LASER SCANNER BASED ON AN ELECTROTHERMAL TRIPOD MEMS MIRROR FOR LIDAR

Dingkang Wang[1], Connor Watkins[1], Sanjeev Koppal[1], Mengyuan Li[2], Yingtao Ding[2] and Huikai Xie
[1]*University of Florida, USA and* [2]*Beijing Institute of Technology, CHINA*

Low-cost LiDAR with compact omnidirectional 360° scanners are needed for automotive and robotics. This paper reports such a compact omnidirectional scanner based on an electrothermal MEMS mirror, in which a circular pattern is generated by a two-axis tripod electrothermal MEMS mirror at non-resonant mode and consecutively converted to a 360° horizontal scan by a cone mirror. Meanwhile the vertical scanning FoV up to 8° is also achieved.

T3P.059 A REFLECTION TYPE VAPOR CELL BASED ON LOCAL ANODIC BONDING OF 45° MIRRORS FOR MICRO ATOMIC CLOCKS

Hitoshi Nishino[1], Masaya Toda[1], Yuichiro Yano[2], Masatoshi Kajita[2], Tetsuya Ido[2], Motoaki Hara[2], and Takahito Ono[1]
[1]*Tohoku University, JAPAN and* [2]*National Institute of Information and Communications Technology, JAPAN*

This paper reports the design, fabrication and evaluation of a reflection-type micro Rb vapor cell fabricated by local anodic bonding of small 45° mirrors. The 45° mirrors with a Bragg mirror are fabricated by using dicing process. The vapor cells having horizontal cavity with the 45° mirrors at the both ends are fabricated by anodic bonding process. Optical absorption of Rb and CPT (Coherent Population Trapping) resonance for atomic clock operation are evaluated.

T3P.060 A SILICON PHOTONIC MEMS MATRIX SWITCH USING DIRECTIONAL COUPLERS IN COMPARISON WITH THAT USING ADIABATIC COUPLERS

Takumi Nagai and Kazuhiro Hane
Tohoku University, JAPAN

A silicon photonic waveguide matrix switch using movable directional couplers is designed, fabricated and tested. Since the directional coupler (10μm) is shorter than our previous adiabatic coupler (50μm), the size of matrix switch can be decreased. The port isolation and the insertion loss of a switch cell was 16.7dB and less than 1dB, respectively. A 4 x 4 matrix switch was also fabricated. The wavelength dependence of directional coupler can be compensated by adjusting coupler gap.

T3P.061 BULK PZT ACTUATOR BASED SCANNING MICROMIRROR WITH INTEGRATED DEFLECTION ANGLE SENSOR

Jeong-Yeon Hwang and Chang-Hyeon Ji
Ewha Womans University, KOREA

This paper presents a new type of piezoelectrically actuated scanning micromirror using bulk PZT plate and integrated electromagnetic deflection angle sensor. Proposed actuation mechanism utilizes a commercially available bulk PZT plate attached to a silicon substrate using adhesive. Fabricated device is experimentally characterized and analyzed using finite element analysis. An optical scan angle of 45º at 28.4kHz has been achieved at 50Vpp square wave input.

T3P.062 EXPERIMENTAL DETECTION OF PIEZO-TUNABLE MICRO-LENS PERFORMANCES BY SPOT OPTICAL MEASUREMENTS

Sabina Merlo[1], Eleonora Crisà[1], Marco Ferrera[2], and Marco Soldo[2]
[1]*University of Pavia, ITALY and* [2]*STMicroelectronics, ITALY*

We present the experimental results of testing piezo-electrically tunable micro-lenses (Tlens®) using a single-spot optical setup that combines interferometric sensing of low-frequency dynamic deformations with direct detection of dioptric power, as functions of the driving voltage of the thin-film piezo-actuator. Measurements can be carried out in a fast sequence, thus allowing a direct comparison among the lens characteristics, before and after electrical pulses for piezo imprint.

T3P.063 FUNCTIONAL PLASMONIC FIBER-OPTIC BASED SENSORS USING LOW-COST MICROSPHERE PHOTOLITHOGRAPHY

Jiayu Liu[1], Ibrahem Jasim[1], Muhammad Roman[2], Yuyao Yang[1], Chuang Qu[2], Jie Huang[2], Edward Kinzel[3], and Mahmoud Almasri[1]
[1]University of Missouri, USA, [2]Missouri University of Science and Technology, USA, and [3]University of Notre Dame, USA

We present a technique using microsphere lithography for the low-cost fabrication of plasmonic fiber-optic based refractive-index sensors. The sensor is capable to low concentration of glucose down to 33 mg/ml.

T3P.064 INTEGRATED AIR SPACED TERAHERTZ METAMATERIAL ABSORBER WITH HIGH QUALITY FACTORS

Chunxu Chen[1], Sultan Can[1,3], Jacob Schalch[2], Xiaoguang Zhao[1], Guangwu Duan[1], Richard Averitt[2], and Xin Zhang[1]
[1]Boston University, USA, [2]University of California San Diego, USA and [3]Ankara University, TURKEY

We present a polarization insensitive high quality factor air spaced triple band metamaterial perfect absorber (MMPA). With air instead of the traditional dielectric layer, the MMPA exhibits an extremely high quality factor (Q). We also demonstrate that the coupling between the metamaterial layer and the ground plane is the primary cause for the difference between the theoretical and the experimental results.

T3P.065 LARGE SCALE MANUFACTURING OF HYBRID TERAHERTZ METAMATERIAL SURFACES VIA WAFER-LEVEL WATER LITHOGRAPHY

Zhen Liu[1,2], Zhitao Zhou[1], Keyin Liu[1], Ting Xiao[2], Tiger H. Tao[1], and Jianjuan Jiang[1]
[1]Chinese Academy of Sciences (CAS), CHINA and [2]Shanghai Normal University, CHINA

We report a facile method of fabricating large scale tunable hybrid terahertz (THz) metamaterial surfaces. The THz metamaterial surfaces consist of zirconium dioxide microsphere arrays which are self-assembled on the substrate using a wafer-level water lithography. Specifically, the resonance of the ZrO_2 microspheres/silk composite structure can be dynamically tuned over a broad THz frequency range by varying the morphology of the dot array on silk substrate by water vapor treatments.

T3P.066 OUT-OF-PLANE DIRECTION THERMAL ACTUATER FOR OPTICAL MEMS

Mario Kiuchi, Naoki Okimoto, Yasuyuki Hirata, Gen Matsuoka, and Osamu Torayashiki
Sumitomo Precision Products Co., Ltd., JAPAN

We develop two types of novel out-of-plane direction thermal actuators composed of only single crystal silicon for optical MEMS. These thermal actuators have advantages of large force at low voltage, large displacement, high reliability and easy fabrication compared with other types of actuators. The first type of actuators could tilt the mirror drastically. The latching mechanism by using the second type of actuators could strongly hold the optical shutter after the displacement.

T3P.067 S/N IMPROVEMENT OF AU/SI NANO-ANTENNA PHOTODETECTOR USING SMALL DEVICE AREA AND CONVERGING LENS

Kazuki Kobayashi[1], Yoshiharu Ajiki[2], and Tetsuo Kan[1]
[1]University of Electro-Communications, JAPAN and [2]Olympus Corporation, JAPAN

This paper reports on S/N improvement of Au/Si nano-antenna photodetector by converging light onto a small device area. The infrared light energy was efficiently absorbed by Au nano-antenna is transduced to photocurrent by the Schottky barrier formed on Cr/n-Si interface. When the device area was reduced to 1/25, the amount of dark current noise decreased by about 1/2. By converging the incident laser diameter to 1/10 of the initial spot size, S/N improved about 5 times at 1500 nm.

T3P.068 ULTRASMALL LINE SCAN NONLINEAR OPTICAL MICROSCOPE USING 1D DICHROIC MEMS SCANNER AND SIOB ASSEMBLY

Jin Cheng[1], Weiguo Liu[1], Shun Zhou[1], Naitao Xu[2], Murat Yildirim[3], and Yingshun Xu[3]
[1]Xi'an Technological University, CHINA, [2]China Key System Integrated Circuit Co., Ltd. (CKS), CHINA, and [3]Massachusetts Institute of Technology, USA

This paper reports an ultrasmall line scan nonlinear optical microscope (ULSNLO microscope) with a twelve-fold reduction in overall volume compared to state-of-the-art design, which benefits from integrating, for the first time, a 1D dichroic MEMS scanner with a SiOB (silicon optical bench) assembly. This ULSNLO microscope will enable head-mounted fast functional brain imaging of freely-moving animals for neuroscience study.

Wednesday - Integrated Photonics and Optical MEMS

W3P.058 A HYBRID PNEUMATIC AND PIEZOELECTRIC 3D MICRO SCANNER FOR CANCER IMAGING

Ran Fan[1], Ali Moallemi[1], Yunshan Zhang[1], Lei Chen[1], Yuan Zhao[2], Zhenguo Wu[1], Ryozo Nagamune[1], Keng Chou[1], Haishan Zeng[2], and Mu Chiao[1]
[1]University of British Columbia, CANADA and [2]BC Cancer Agency Research Center, CANADA

We develop a new MEMS confocal scanner based on pneumatic and piezoelectric actuators. Confocal scanning has been realized by actuating an objective lens in out-of-plane direction using a pneumatic actuator and an optical fiber in lateral directions using two piezoelectric actuators. The novelty is in the hybrid pneumatic and piezoelectric actuators. We demonstrate 3D scanning of a 785nm laser, and the new confocal system could assist clinicians to accurately identify lesions in the future.

W3P.059 AN ALIGNMENT SCHEME FOR LOW COST AND HIGH PRECISION SIOB FABRICATION USING AN ELECTROMAGNETIC MICROACTUATOR WITH 5 DOF

Chih-Chung Chen, Yu-Min Fu, Hsin Feng Hsu, and Yu-Ting Cheng
National Chiao Tung University, TAIWAN

This paper presents an alignment scheme for SiOB fabrication using an electromagnetic force-driven microactuator with 5DOF of movement. The actuator comprising four sets of corrugated springs and microcoils driven by with Lorentz and reluctant force respectively can accomplish linearly horizontal and vertical displacement and tilt angle ranging within 2 and 10.5μm, and 1° for positioning optical lens with a resolution of 0.1μm experimentally validated to facilitate the scheme.

W3P.060 AU NANO-SPIRAL STRUCTURE FOR CIRCULAR DICHROIC FILTER IN VISIBLE REGION

Gaku Furusawa[1], Takashi Sekiya[2], Hiroaki Nakamura[2], and Tetsuo Kan[1]
[1]University of Electro-Communications, JAPAN and [2]Idemitsu Kosan Co., Ltd., JAPAN

We report a film with Au nano-spiral structures to behave a circular dichroic filter in visible light region. Rotating Si wafer while cooling to -100 degree and irradiation of the thermal vapor of Au from an angle of 85 degrees created nano-spiral structures with a diameter of about 100 nm on the Si. The fabricated spiral structure was transferred to Scotch tape to form a film. The transmitted light was measured and it was found that it has strong circular dichroism in the visible light region.

W3P.061 CMOS COMPATIBLE FABRICATION OF MID INFRARED MICROSPECTROMETERS BASED ON AN ARRAY OF METAMATERIAL ABSORBERS

MohammadAmir Ghaderi[1], Peter Enoksson[1], and Reinoud F. Wolffenbuttel[2]
[1]Chalmers University of Technology, SWEDEN and [2]Delft University of Technology, THE NETHERLANDS

A mid-IR microspectrometer based on an array of differently tuned narrow-band metamaterial absorbers is presented. The spectral response is tailored by design of the unit cell. Each spectral band is composed of a thermopile detector with an Al-based metamaterial absorber fabricated as CMOS compatible post-process. The design and fabrication method utilized here, enables the CMOS fabrication of integrated large-area plasmonic components on thermal detectors.

W3P.062 FABRICATION AND INTEGRATION OF BINARY PHASED FRESNEL LENS AND MICRO LINEAR ACTUATOR FOR IR LASER BEAM SCANNING APPLICATION

Hsueh-Yu Lu, Chi-En Lu, Zi-Rong Huang, Shihwei Lin, Sung-Cheng Lo, Rongshun Chen, and Weileun Fang
National Tsing Hua Univsersity, TAIWAN

This study presents a MEMS IR-laser beam scanning system consisted of the micro Fresnel lens and linear comb actuators. The merits of this study is to fabricate and further integrate the binary phase Fresnel lens, micro springs, and micro electrostatic actuators through the silicon micromachining processes. Measurements indicate the scanner has a resonant frequency of ~2 kHz, and a displacement of greater than ±20μm. Moreover, the 1550nm Infrared laser beam has a deflection angle of ±6.84°.

W3P.063 IMPROVED PERFORMANCE OF FIBER-OPTIC LOCALIZED SURFACE PLASMON RESONANCE SENSOR VIA GOLD CAPPING AND ANTI-REFLECTION SURFACE

Hyeong-Min Kim[1], Se-Woong Bae[1], Jae-Hyoung Park[1], Dae Hong Jeong[2], Ho-Young Lee[3], and Seung-Ki Lee[1]
[1]Dankook University, KOREA, [2]Seoul National University, KOREA, and
[3]Seoul National University Bundang Hospital

We develop and optimize gold capping process based on seed-mediated growth of nanoparticles, where proposed sensor is more durable and sensitive than conventional fiber optic localized surface plasmon resonance sensors. Signal-to-noise ratio is also enhanced by forming the anti-reflection structure on optical fiber surface. As a feasibility test, the thyroglobuline associated with thyroid cancer is detected.

W3P.064 LIQUID MICROLENS ENABLING TUNABLE FOCUS AND TILT FOR RESOLUTION ENHANCEMENT OF 3D IMAGE

Seungwan Seo, Sung Keun Yoo, Jeong A. Kim, Dongjun Moon, and Seungwan Seo
Osong Medical Innovation Foundation, KOREA

This paper reports a novel method to tune the focus distance and beam tilt angle of an electrowetting on dielectric (EWOD) liquid microlens encapsulated by polymer film. The tunability of focus in 3 dimensionally can be achieved by lateral shift of inner lens and the change of the refractive curvature in planar substrate.

W3P.065 NANOSTRUCTURED AL SWG REFLECTORS ON THIN LP-SI_3N_4 MEMBRANES AS (TIO_2/SIO_2) BRAGG REFLECTOR ALTERNATIVE FOR VIS FABRY-PÉROT INTERFEROMETERS

Christian Helke[1], Karla Hiller[1], Jan Seiler[1], Jens Wolfram Erben[2], Thomas Werner[2], Danny Reuter[2], Marco Meinig[2], Steffen Kurth[2], and Thomas Otto[2]
[1]Chemnitz University of Technology, GERMANY and [2]Fraunhofer ENAS, GERMANY

We present a Fabry-Pérot-Interferometer for the VIS-range from 555 nm to 585 nm. Two approaches for the FPI reflector are investigated: a (TiO_2/SiO_2) Bragg reflector on 210 nm thin freestanding LP-Si_3N_4 membranes as well as a 50 nm thin Al SWG reflector with 140 nm structure dimension and 200 nm structure pitch on 150 nm thin freestanding LP-Si_3N_4 membranes. Reflectance is up to 97 % realizing a FPI with peak transmittance of 40 %, a FWHM bandwidth of 1.8 nm and a free spectral range of 30 nm.

W3P.066 PHOTO-REGULATED RECONFIGURABLE ARITHMETIC CIRCUITS USING PHYSICALLY TRANSIENT DIFFRACTIVE OPTICS

Xiaoqing Cai[1,], Zihan Gao[2], Tiger H. Tao[1,2], and Jianjuan Jiang[1]
[1]Chinese Academy of Sciences (CAS), CHINA and [2]Shanghai University, CHINA

We report physically transient diffractive optical elements (DOEs) for inducing photo-regulated reconfigurable arithmetic circuits. The silk-based DOE can easily regulate the luminous intensity and distribution of diffractive light spots applied to tune the property of the photoresistors. By precisely controlling the performance of various photoresistors, it provides a novel way for realizing reconfigurable arithmetic circuits.

W3P.067 TRACEABLE LASER POWER MEASUREMENT USING A MICRO-MACHINED FORCE SENSOR WITH SUB-PICONEWTON RESOLUTION

Zhi Li[1], Sai Gao[1], Uwe Brand[1], Karla Hiller[2], Susan Hahn[2] and Helmut Wolff[1]
[1]Physikalisch-Technische Bundesanstalt, GERMANY and [2]Technical University Chemnitz, GERMANY

We develop a micro-machined pico-force transducer with integrated Fabry-Perot resonator for traceable measurement of the laser power with high resolution and relatively large measuring range. This silicon MOEMS transducer uses AFM cantilevers with high reflection coating for various wavelengths as the reflector for laser power measurement. First measurements of the radiation pressure of a semiconductor laser revealed a noise limitation of the pico-force transducer of <1 pN.

Monday - Materials, Fabrication, and Packaging Technologies

M3P.067 A CONTINUOUS CELLULAR AUTOMATON SIMULATION MODEL OF FOCUSED ION BEAM INDUCED DEPOSITION PROCESS FOR MICRO/NANO STRUCTURES

Chen Fang, Qianhuang Chen, Qing Chai, Yan Xing, and Xiaohui Lin
Southeast University, CHINA

We propose a continuous cellular automaton simulation model of focused ion beam induced deposition process. This model takes the distribution of precursor gas, diffusion effect and sputtering during deposition into account to get more accurate net deposition velocity. Pillars are fabricated as an experimental group to make comparison with the simulation group having the same parameters. In fact, they match well in height and diameter.

M3P.068 A SCALABLE 3-D PRINTED BIOLOGICAL ASSEMBLY TECHNOLOGY

Sangwook Chu, Adam D. Brown, James N. Culver, and Reza Ghodssi
University of Maryland, USA

We present a scalable biological assembly on three-dimensional electrodes enabled by electro-bioprinting (EBP). A highly uniform assembly of proteins – cysteine-modified Tobacco mosaic virus and glucose oxidase – on micropillar array electrodes is achieved, enabled by selective and sequential EBP of biological inks. This work demonstrates a highly controllable biofabrication technique for creating advanced bioelectronics including bio -sensors and -energy harvesting systems.

M3P.069 EMBEDDED COMPONENT PACKAGING FOR WAFER-LEVEL ENCAPSULATED AND INTEGRATED RF MEMS

Rameen Hadizadeh[1], Anssi Laitinen[1], David Molinero[1], Shawn Cunningham[1], Christian Vockenberger[2], and Gerald Weis[2]
[1]WiSpry, Inc., USA and [2]Austria Technologie and Systemtechnik, AUSTRIA

We have demonstrated the successful embedding of a wafer-level encapsulated, CMOS integrated RF MEMS tuner inside the fiberglass and epoxy resin core of an organic laminate substrate. The MEMS thin-film hermetic cavity has been proven to withstand the mechanical stress of substrate embedding. RF performance was evaluated, and electrostatic discharge (ESD) protection was characterized with the integration of surface-mount passive inductor components.

M3P.070 FABRICATION OF PARTLY ENCAPSULATED VERTICAL NANOELECTRODES FOR AN INTRACELLULAR MICROELECTRODE ARRAY

Sonja Allani, Andreas Jupe, Holger Kappert, and Holger Vogt
Fraunhofer IMS, GERMANY

We present a concept and proof of principle regarding a fabrication technique for vertical nanoelectrodes. CMOS-compatible processes are applied to produce three dimensional tubes which are partly encapsulated by an insulation layer. An extended sacrificial layer technique using deep reactive ion etching and atomic layer deposition was developed. The resulting nanoelectrodes can lead to a novel device for a bidirectional interface between integrated circuits and cells' interior.

M3P.071 FINE-PITCH BONDING METHODS FOR INTEGRATING ASICS WITH FLEXIBLE POLYMER MEMS

James J. Yoo and Ellis Meng
University of Southern California, USA

We developed and adapted multiple robust, high-yield processes to achieve fine-pitch bonding of ASICs directly into flexible polymer MEMS to facilitate large-scale high-density neural probe arrays. Bonds were made via wedge bonding, conductive epoxy, anisotropic conductive film, and a novel polymer-ultrasonic-on-bump technique, all at low temperature (≤100 °C) and fine pitch (100 μm) with yields of 83% or greater. Bonded devices were subjected to thermal and mechanical reliability tests.

M3P.072 HIGH-YIELD TRIPLE-STACK BONDING FABRICATION PROCESS FOR MICROMACHINED MICROMOTORS WITH CONTACTLESS ROTOR

Boqian Sun, Shunyue Wang, Yidong Tan and Fengtian Han
Tsinghua University, CHINA

We optimize a glass-silicon triple-stack bonding strategy with low bonding voltage applied on MEMS devices with movable structures which has achieves a significant improvement in the yield.

M3P.073 INTEGRATION OF MEMS FLOW SENSOR, ELECTRICAL WIRING, AND TUBE STRUCTURE ONTO COPPER ON POLYIMIDE SUBSTRATE

Ryusei Takigawa[1], Yoshihiro Hasegawa[1], Kazuhiro Taniguchi[1], Miyoko Matsushima[2], Tsutomu Kawabe[2], and Mitsuhiro Shikida[1]
[1]Hiroshima City University, JAPAN and [2]Nagoya University, JAPAN

A MEMS flow sensor, an electrical wiring, and a flow tube structure were integrated onto the same substrate. A Cu on polyimide (COP) was used as the sensor substrate. Both sensor devices composed of a heater working as flow sensor and a temperature sensor, and electrical wiring were fabricated in the same substrate. The signal lines in the sensor device were automatically connected to the electrical wiring formed into the Cu layer during the fabrication without an electrical bonding process.

M3P.074 LOW-COST, METAL-BASED MICRO-NEEDLE ELECTRODE ARRAY (M-MNEA): A THREE-DIMENSIONAL INTRACORTICAL NEURAL INTERFACE

Junshi Li, Dong Huang, Yufeng Chen, and Zhihong Li
Peking University, CHINA

This paper reports a novel intracortical neural interface comprising metal-based micro-needle electrode array (M-MNEA) with the height ranging from hundreds of microns to millimeters. The low-cost fabrication process of the device contains simple techniques and without any step of lithography or complex etching. Meanwhile, the M-MNEA ensures the biocompatibility and safety compared with brittle silicon needles.

M3P.075 METAL-ASSISTED CHEMICAL ETCHING METHOD SUBJECTED TO MICRO/NANO DEVICE FABRICATION

Nguyen Van Toan[1], Xiaoyue Wang[1], Naoki Inomata[1], Masaya Toda[1], Ioana Voiculescu[2], and Takahito Ono[1]
[1]Tohoku University, JAPAN and [2]City of New York, USA

This work reports the metal-assisted chemical etching (MACE) technique along with applying for micro/nano systems. To exemplify this technique, we demonstrate the fabrications of different microelectromechanical systems (MEMS) devices; from simple structure (micro-cantilever) to a complex structure (capacitive silicon resonator).

M3P.076 MICROMETER-SIZED SUCTION CUP ARRAY WITH STRONG ADHESION TO WET SURFACE

Thanh-Vinh Nguyen[1] and Isao Shimoyama[2]
[1]National Institute of Advanced Industrial Science and Technology (AIST), JAPAN and [2]Toyama Prefecture University, JAPAN

We present a flexible adhesive pad which is covered with a dense array of micro suction cup array whose base diameter is 100μm. We show that the adhesion of the micro suction cup array dramatically increases when the surface was wet, with a maximum adhesion strength of 0.37 MPa, which is more than 3 times higher than the theoretical limit of a passive suction cup. Moreover, the adhesion force is independent of the surface wettability and surface tension of the lubricated liquid.

M3P.077 NANOFABRICATION OF CHALCOGENIDE GLASS FOR INFRARED SENSORS

Le Wei, Liang Dong, and Meng Lu
Iowa State University, USA

This paper reports a novel nanofabrication approach that combines imprint and silver doping lithography (I-SDL) to realize nanopatterns in chalcogenide (ChG) films. It is possible to precisely manipulate silver doping into a ChG film in all three dimensions at a nanoscale. High-resolution 1D and 2D ChG gratings have been realized. Optical resonances supported by the patterned ChG grating are investigated.

M3P.078 ROOM TEMPERATURE DIRECT WRITING OF ULTRATHIN ZINC OXIDE PIEZOELECTRIC FILMS VIA NEAR-FIELD ELECTROHYDRODYNAMIC JETTING FOR HIGH-FREQUENCY FLEXIBLE ELECTRONICS

Brenda García-Farrera[1,2] and Luis Fernando Velásquez-García[1]
[1]Massachusetts Institute of Technology, USA and [2]Tecnológico de Monterrey, MEXICO

We report the first demonstration of a novel, low-cost, and low-temperature process for printing piezoelectric ultrathin films via nearfield electrohydrodynamic deposition and zinc oxide (ZnO) nanoparticle solutions. The technique is compatible with rigid, flexible, conductive, and insulating substrates, and yields ZnO imprints that are significantly arranged in the (100) crystal orientation – achieving net piezoelectricity.

M3P.079 SiC CANTILEVERS FOR GENERATING UNIAXIAL STRESS

Boyang Jiang[1], Noah Opondo[1], Gary Wolfowicz[2], Pen-Li Yu[1], David D. Awschalom[2], and Sunil A. Bhave[1]
[1]Purdue University, USA and [2]University of Chicago, USA

This work demonstrates the very first cantilever resonators fabricated from bulk High Purity Semi-insulating 4H Silicon Carbide wafers. Our innovations include: (1) front and back side Deep Reactive-Ion Etching (DRIE) to release the cantilever devices; (2) the first use of the bulk High Purity Semi-Insulating (HPSI) 4H-SiC material in fabrication of cantilevers; (3) measurements of high quality resonance modes with Laser Doppler Vibrometer (LDV).

M3P.080 THERMAL SENSATION DISPLAY WITH CONTROLLABLE THERMAL CONDUCTIVITY

Seiya Hirai and Norihisa Miki
Keio University, JAPAN

We demonstrate a thermal sensation display that can present various thermal sensation by varying the thermal conductivity of the display. The device contains liquid metal, whose contact to the top titanium plate determines the thermal conductivity of the device and thus, the thermal sensation presented to the user. Using this device, for the first time, we can correlate the thermal sensation to the thermal conductivity in a quantitative manner.

M3P.081 TITANIUM NITRIDE NANOTUBES ELECTRODES USED FOR CHRONIC NEURAL STIMULATION

Gui Chen, Marcella Gatti, and Mark Ming-Cheng Cheng
Wayne State University, USA

This paper presents corrosion-resistant and high-capacity implantable titanium nitride (TiN) nanotubes electrodes for neural probes applications. To research smaller electrodes to minimize tissue damage, high aspect ratio TiN nanotube structures were fabricated using electrochemical anodization of Ti wires followed by high-temperature nitration. The specific charge capacity of nanoporous TiN correlates proportionally with the surface area and pore size.

M3P.082 TSV-FREE VERTICAL INTERCONNECTION TECHNOLOGY USING AU-SI EUTECTIC BONDING FOR MEMS WAFER-LEVEL PACKAGING

Hengmao Liang, Song Liu, and Bin Xiong
Chinese Academy of Sciences (CAS), CHINA

We develop a TSV-free vertical interconnection technology using Au-Si eutectic bonding applied on MEMS wafer-level packaging (WLP), which simplifies processes and promotes all-Si fabrication abilities in MEMS 3D WLP. By forming Au-Si ohmic contacts in Au-Si bonding, it is cost-efficacious to employ low-resistivity Si columns in Cap wafers as vertically electrical pathways while sealing. Also the proposed method is validated by tests on signal interfacing and hermetic packaging for MEMS devices.

M3P.083 WAFER-LEVEL FABRICATION PROCESS FOR MICRO HEMISPHERICAL RESONATORS

Yan Shi, Xiang Xi, Yulie Wu, Wei Li, Kun Lu, Zhanqiang Hou, Xuezhong Wu, and Dingbang Xiao
National University of Defense Technology, CHINA

This paper reports a wafer-level fabrication process for micro hemispherical resonators. Fused silica 3-D structures are formed by high-temperature glassblowing individually, following processes including ultrafast laser ablation, metallization and bonding to electrode wafer are accomplished on wafer level. Accompished devices with capacitive gaps about 15 micro are characterized through capacitive measurement in vacuum.

Tuesday - Materials, Fabrication, and Packaging Technologies

T3P.069 A MICROMACHINED IONIC LIQUID ION SOURCE WITH FLOW-CONTROLLED SEGMENTED ANNULAR CHANNELS

Nguyen-Van Chinh, Le-Van Minh, Takahito Ono, and Hiroki Kuwano
Tohoku University, JAPAN

In this work, we present a micromachined fluorine-based ion source for nano-/micro-processing applications. Our proposed structure composed an out-of-plane Si micro-emitter surrounded by four segmented annular micro-channels for controlling the ionic liquid supplied flow to the tip emitter, enabling to broaden the working regime and overcome the droplet emission. The reactive fluorine-based ions were emitted from the fabricated ionic liquid ion source and used for patterning Si structure.

T3P.070 COMPARISION OF DEEP ETCHED BOROSILICATE GLASSES IN A FLUORINE BASED PLASMA

Christoph Weigel[1], Stefan Sinzinger[1], and Martin Hoffmann[2]
[1]Technische Universität Ilmenau, GERMANY and [2]Ruhr-Universität Bochum, GERMANY

We present a structuring process for complex borosilicate glasses with different amounts of non-volatile reaction products using a fluorine based plasma. The influence of material and gas composition on the etch rate, selectivity, sidewall angle and roughness are discussed. It is shown that non-volatile products on the etched sidewall has a strong influence on the structure profile. Furthermore, the effect of the dielectric constant and the thermal conductivity are discussed briefly.

T3P.071 FABRICATION OF HIGH ASPECT-RATIO MICROSTRUCTURE ON IMPROVED TITANIUM SUBSTRATE WITH EXCELLENT ADHESIVE STRENGTH AND SU-8 PHOTORESIST

Liyan Lai, Yongpeng Wu, Yunna Sun, Zhuoqing Yang, Guifu Ding, and Xiaolin Zhao
Shanghai Jiao Tong University, CHINA

We develop an anodic oxidation method for improving the adhesion strength between SU-8 photoresist and titanium substrate. The adhesion was increased by approximately 86% through anodic oxidation treatment compared to Si wafer substrate. The high aspect ratio (24) SU-8 micropillar arrays with 600 μm height were fabricated without any distortion, collapse and delamination. The treated substrate can also serve as seed layer for electroplating.

T3P.072 FACILE, PACKAGING SUBSTRATE-AGNOSTIC, MICROFABRICATION AND ASSEMBLY OF SCALABLE 3D METAL MICROELECTRODE ARRAYS FOR *IN VITRO* ORGAN-ON-A-CHIP AND CELLULAR DISEASE MODELING

Charles M. Didier, Avra Kundu, and Swaminathan Rajaraman
University of Central Florida, USA

We present a novel, packaging-substrate agnostic, microfabrication and assembly technology for the rapid development of 3D metal foil Microelectrode Arrays (MEAs), for in vitro organ-on-a chip and cellular disease modeling assays. Fully insulated and laser-defined metal foil MEAs are demonstrated on both custom 3D-printed substrates and glass wafer substrates. Characterization of the MEAs is demonstrated, along with Scanning Electron Microscopy imaging for electrode definition confirmation.

T3P.073 HIERARCHICAL 3D DANDELION FLOWER-LIKE GAN MICROSPHERE FOR HUMIDITY SENSOR WITH EXCELLENT LINEARITY RESPONSE

Manimuthu Veerappan, Xiaohui Leng, Ramachandran Rajendran and Fei Wang
Southern University of Science and Technology, CHINA

This paper presents gallium nitride material with hierarchical 3D dandelion-like microsphere structure for humidity sensing. Innovations include: (i) development ofammonothermal-conjugated ammonification hybrid approach; (ii) the first-ever use of oleylamine for morphology determination; and (iii) excellent linearity and response higher than three orders of magnitude within the wholemeasurement range.

T3P.074 INDUSTRIAL GRADE FABRICATION OF NANOWIRE SENSOR DEVICE EXPLOITING SACRIFICIAL SHADOW PATTERNING METHOD

Min-Seung Jo, Min-Ho Seo, Kwang-Wook Choi, Jae-Shin Lee, Jae-Young Yoo, Hyeon-Joo Song, and Jun-Bo Yoon
Korea Advanced Institute of Science and Technology (KAIST), KOREA

We developed a wafer-level uniformly size-controlled nanowire fabrication method can simply fabricate remarkably small nanowires (sub-50 nm) with wide material selection; importantly, the fabricated nanowires have ultra-high size uniformity on the 4-inch wafer. By using this method, we demonstrate nanowire-based hydrogen gas sensors which performed highly uniform sensitivity owing to the geometrical uniformity of the fabricated nanowires.

T3P.075 MAGNETOSTRICTIVE PERFORMANCE OF ELECTRODEPOSITED $TB_XDY_{(1-X)}FE_Y$ THIN FILM

Hang Shim[1], Kei Sakamoto[1], Naoki Inomata[1], Masaya Toda[1], Nguyen Van Toan[1,2], Yunheub Song[2], and Takahito Ono[1]
[1]Tohoku University, JAPAN and [2]Hanyang University, KOREA

This paper presents the process technology of microstructures fabrication of a magnetostrictive thin film TbxDy(1-x)Fey for magnetic actuation, and the magnetostictive actuation performances are evaluated. The thin film are deposited by and electrodeposition method using three electrode system. Bi-material cantilever structures are fabricated by microfabrication, and the magnetic responses are measured.

T3P.076 METHOD FOR STRONG PARYLENE-C BONDING TO SURFACES CONTAINING GOLD AND SILICON DIOXIDE

Sander van den Driesche, Christian Habben, André Bödecker, and Michael J. Vellekoop
University of Bremen, GERMANY

This paper presents the characterization of a method to solve the adhesion problem between parylene-C and gold containing surfaces. The adhesion is achieved by chemical linkage. Novel aspects include: i) new primer process to allow parylene coatings on surfaces consisting of both gold and silicon dioxide; ii) proving the adhesion quality by standard autoclave tests at 121°C for 15 minutes. Our approach is easily adaptable in the parylene-C deposition process and suitable for biomedical devices.

T3P.077 MICROPOWDER BLASTING SIMULATION WITH BLASTING MICROPOWDER SIZE AND MASK EROSION USING CELLULAR AUTOMATON

Yoshitaka Nagase and Hiromasa Yagyu
Kanto Gakuin University, JAPAN

This paper presents a micropowder blasting simulation for the first time to predict a processed glass microstructure with taking account of blasting micropowder size and mask erosion. The newly developed simulator was utilized cellular automaton algorithm with solid particle erosion model for three-dimensional cell and includes a contact calculation between micropowder and surface of the objects. The simulated line patterns were successfully verified by comparing with experimental results.

T3P.078 NANOELECTROMECHANICAL LOGICAL GATES UTILISING SELECTIVE TUNGSTEN CHEMICAL VAPOR DEPOSITION

Nguyen Van Toan[1], Dong Zhao[1], Naoki Inomata[1], Masaya Toda[1], Yunheub Song[2], and Takahito Ono[1]
[1]Tohoku University, JAPAN and [2]Hanyang University, KOREA

NAND and NOR logical gates based on the electrostatically driven silicon nanoelectromechanical (NEM) switches coated tungsten (W) are designed, fabricated and evaluated. A selectively conformal W deposition on high aspect ratio silicon structures is investigated. Logical gates are successfully fabricated and all their functions have been proved. This work opens the possibility not only for producing the complex mechanical logic systems but also for a way to reducing capacitive gap width.

T3P.079 NOVEL DESIGN AND FABRICATION OF SILICON NANOWIRE ARRAY ON (111) SOI

Zicheng Lu, Yuelin Wang, and Tie Li
Chinese Academy of Sciences (CAS), CHINA

We design and fabrication a novel Silicon NanoWire (SiNW) array over the buried-oxide layer of (111) Silicon-On-Insulator by using conventional microfabrication methods. To enhance the regulation of the nanowire size, besides the silicon wall, the thickness of top silicon is added to adjust the width. The suspended nanowires located at the bottom of the cavity are more stable and robust than our previous reported SiNW array which is at the top of the cavity.

T3P.080 STRAIN SENSOR BASED ON OPTICAL INTENSITY CHANGE THROUGH THE CARBON NANOTUBE EMBEDDED ELASTOMER

Jimin Gu, Donguk Kwon, Junseong Ahn, and Inkyu Park
[1]Korea Advanced Institute of Science and Technology (KAIST), KOREA

We develop the strain sensor based on an optical intensity change through the nanofiller-embedded elastomer for the human motion detection system. The optical transmittance based strain sensor principles were analyzed and the sensor characteristics were carried out to show the sensor performances. To show the human motion detection probability, the sensor is applied to the human joint motion detection.

T3P.081 THREE DIMENSIONAL CORE-SHELL MICRONEEDLE-ELECTRODE FOR MULTISITE NEURONAL RECODING

Shinnosuke Idogawa[1], Yoshihiro Kubota[1], Shota Yamagiwa[1], Hirohito Sawahata[2], Rika Numano[1], Kowa Koida[1], and Takeshi Kawano[1]
[1]Toyohashi University of Technology, JAPAN and
[2]National Institute of Advanced Industrial Science and Technology, JAPAN

We fabricated three-dimensional (3D) core-shell microneedle-electrode array for recording neuronal activities in the brain tissue. Advantage of embedding core-shell electrode in individual microneedle include i) multisite recording, ii) simultaneous stimulation, and iii) high signal to noise ratio (SNR) recording by grounding the shell electrode. This paper demonstrates the first advantage of the multisite neuronal recording using mouse brain tissue in vivo.

T3P.082 TOWARDS NANOSCALE 3D PRINTING OF PDMS-LIKE POLYMERS

Anpan Han, Ding Zhao, Liyun Yu and Anne Ladegaard Skov
Technical University of Denmark, DENMARK

Inside a vacuum chamber, we froze hexamethyldisiloxane vapors into thin-films of ice. We then patterned and crossed-linked the ice-film into silicon containing polymers by electron beam exposure. The unreacted hexamethyldisiloxane is vaporized at room temperature, and the cross-linked siloxane remains as a stable thin-film on the supporting silicon substrate. The chemical composition of the cross-linked silioxane is similar to polydimethylsiloxane (PDMS), that are used in sensor applications.

T3P.083 TWO-DIMENSIONAL CURVING TECHNIQUES FROM FLAT DIFFRACTION GRATING TO CONCAVE DIFFRACTION GRATING

Takanori Aono[1], Yoshisada Ebata[2], Kenta Yaegashi[2], and Shigeru Matsui[2]
[1]Hitachi, Ltd., JAPAN and [2]Hitachi High Technologies Corporation, JAPAN

This paper evaluated the performance of the concave diffraction grating fabricated with the two-dimensional curving techniques. This concave diffraction grating was fabricated with assembling flat diffraction grating film onto a convex glass and transferring from the convex diffraction grating mold. The diffraction efficiency showed almost the same that of the flat diffraction grating.

T3P.084 ZERO INSERTION FORCE MEMS SOCKET: 3D MULTI-CHIP ASSEMBLY FOR MICROROBOTICS

Hani C. Gomez, Craig B. Schindler, Harry L. Clark Jr, Joseph T. Greenspun, and Kristofer S.J. Pister
University of California, Berkeley, USA

We present the design and characterization of a zero insertion force (ZIF) MEMS socket used for 3D multi-chip assembly of microrobots. Successful assemblies between the ZIF socket and a linear MEMS motor, as well as the ZIF socket and a microrobotic leg are demonstrated. Contact resistance versus force plots for various sputtered metals are used to show the characterization of the electrical connections between the ZIF socket's probes and the inserted chip's pads.

Wednesday - Materials, Fabrication, and Packaging Technologies

W3P.068 A RESONANT PRESSURE MICRO SENSOR BASED ON SUSPENDED ASSEMBLY

Yulan Lu[1,2], Bo Xie[1], Yadong Li[1,2], Deyong Chen[1], Junbo Wang[1], Jian Chen[1], Hua Wei[1], and Guoqing Zhang[1]
[1]Chinese Academy of Sciences (CAS), CHINA and [2]University of Chinese Academy of Sciences, CHINA

We develop, model, and optimize an assembly method for resonant pressure micro sensors which is more stable than conventional assembly methods. To minimize the side effects of environmental noises (e.g., variations in temperature and vibrations) and stabilize intrinsic frequencies of resonators, a suspended assembly method was proposed in this study.

W3P.069 ADVANCED MEMS-ELASTOMER CONFIGURATION FOR ENHANCED SURFACE PLASMON RESONANCE

Kuo-Feng Chiu[1], Yu-Tang Hu[1], Subodh Kumar[2], and Cheng-Yao Lo[1]
[1]National Tsing Hua University, TAIWAN and [2]Universite de Lyon, FRANCE

The proportion of the isotropic strain (ISO) in a microelectromechanical system (MEMS)-elastomer hybrid configuration was enlarged from 6.99% to 98.30% with the proposed MEMS design and its corresponding elastomer arrangement in this work. This achievement was realized by relocating the applied force from a typical configuration and by modifying the shape of the elastomer. The proposed configuration significantly improved the ISO, covering almost complete active area for various applications.

W3P.070 ANALYSIS AND CHARACTERIZATION OF SOFT-LITHOGRAPHY-COMPATIBLE PARALLEL-ELECTRODE-SENSORS IN MICROFLUIDIC DEVICES

Ruxiu Liu, Chia Heng Chu, Mert Boya, Dohwan Lee, Ozgun Civelekoglu, Hang Chen, and A. Fatih Sarioglu
Georgia Institute of Technology, USA

We theoretically and experimentally analyze a parallel-electrode Coulter sensor, where one electrode is formed by a metal layer covering the inner walls of a microfluidic channel. We specifically focus on impedance variances when particles step into the sensing region, and compare the sensitivity with that of conventional coplanar electrodes. Our results demonstrate higher sensitivity of the parallel-electrode sensor over coplanar electrodes.

W3P.071 DEVELOPMENT OF A MICRO-MAGNET FOR THE ELECTROMAGNETIC TRANSDUCTION OF MEMS

Pierre Moritz[1,2], Fabrice Mathieu[2], David Bourrier[2], Daisuke Saya[2], Thomas Blon[1], Klaus Hasselbach[3], Roman Kramer[3], Liviu Nicu[2], Lise-Marie Lacroix[1], Guillaume Viau[1], and Thierry Leichle[2]
[1]LPCNO - INSA Toulouse, FRANCE, [2]LAAS - CNRS, FRANCE, and [3]University of Grenoble, Alpes, FRANCE

We have developed a high performance micro-magnet for electromagnetic MEMS. The magnet is obtained via the magnetophoresis-driven assembly of cobalt nanorods. This MEMS compatible fabrication process leads to a dense structure achieving high coercive field and remanence to saturation magnetization ratio. The magnet performance was evaluated by measuring the magnetic induction with a Hall effect micro-probe and by actuating a silicon micro-cantilever at resonance with good signal to noise ratio.

W3P.072 FABRICATION OF LITHIUM NIOBATE BULK ACOUSTIC RESONATOR FOR 5G FILTERS

Muhammad Faizan[1], Annalisa De Pastina[1], Soumya Yandrapalli[1], Patrick J. Turner[3], Robert B. Hammond[3], Victor Plessky[2], and Luis Guillermo Villanueva[1]
[1]École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND, [2]Resonant Inc., USA, and [3]GVR Trade SA, SWITZERLAND

This work presents the fabrication of a MEMS resonant device which addresses the need for high quality and miniaturized RF filters in the 3–6 GHz range. The 4-mask fabrication process is based on the definition of interdigitated Al electrodes on a suspended membrane of 400 nm-thick Z-cut lithium niobate (LiNbO3). Devices are fabricated with a yield of 70% and exhibit high electromechanical coupling (kt^2) and quality factor (Q) up to 28% and 300 respectively, for frequencies around 5 GHz.

W3P.073 FALSE NEGATIVE FREE NANOPORE FABRICATION VIA ADAPTIVE LEARNING OF THE CONTROLLED DIELECTRIC BREAKDOWN

Kamyar Akbari Roshan, Zifan Tang, and Weihua Guan
Pennsylvania State University, USA

We report a high fidelity moving Z-Score method based controlled breakdown fabrication of solid-state nanopore. Our study elucidates the Joule heating is the dominant mechanism for electric field-based nanopore enlargement. Single DNA molecule sensing using nanopores fabricated by this method was successfully demonstrated.

W3P.074 FOUR-SIDED TIP-SEPARABLE MICRO-NEEDLE DEVICE WITH LARGE BARB FORMED BY ANISOTROPIC WET ETCHING FOR TRANS-DERMAL DRUG DELIVERY SYSTEM

Mizuki Sakamoto, Yoshihiro Hasegawa, Kazuhiro Taniguchi, and Mitsuhiro Shikida
Hiroshima City University, JAPAN

A four-sided tip-separable microneedle with a large barb was proposed for separating a needle tip easily during the skin insertion. The proposed microneedle was composed of a sharp needle tip and a base one, and the former was placed on the latter with the 45° off rotation angle in the needle axis for increasing the barb area. A symmetry property of a single crystallographic Si(100) substrate was applied to produce two Si master needles both tip and base needle structures respectively.

W3P.075 HIGH ASPECT RATIO VIA FILLING BY ELECTROLESS DEPOSITION ENABLED BY SUPERCRITICAL CARBON DIOXIDE

Ho-Chiao Chuang, Tun-Sheng Chang, and Jorge E. Sánchez
National Taipei University of Technology, TAIWAN

We report filling of blind-hole, high aspect ratio (AR) nanotrenches by Ni electroless deposition (ELD) enabled under supercritical carbon dioxide (SC-CO_2). SC-CO_2 ELD effectively filled blind trenches with AR≤1:60 (diameter: 83nm, depth: 5μm), which was ~2x higher compared to that achieved by conventional ELD under similar experimental conditions. No surface pre-treatment to increase wettability was performed, and trench filling was achieved only through application of SC-CO_2.

W3P.076 INTEGRATED HIGH POWER MICRO MAGNETS FOR MEMS SENSORS AND ACTUATORS

Thomas Lisec[1], Mani Teja Bodduluri[2], Arne-Veit Schulz-Walsemann[1], Lars Blohm[1], Isa Pieper[1], Shanshan Gu-Stoppel[1], Florian Niekiel[1], Fabian Lofink[1], and Bernhard Wagner[1]
[1]Fraunhofer ISIT, GERMANY and [2]Christian Albrecht University of Kiel, GERMANY

Back-end-of-line compatible integration of NdFeB-based micro magnets onto 8 inch silicon substrates is described. Permanent magnetic structures with dimensions between 25μm and 2000μm and a depth up to 600μm can be fabricated reliably and reproducibly. Processes at up to 400°C can be applied during post-processing of the substrates. To demonstrate post-processing capabilities, high-power micro magnet arrangements embedded in silicon frames of various shapes are presented.

W3P.077 MEMS ENABLED FAST TIME-RESOLVED X-RAY DIFFRACTION CHARACTERIZATION PLATFORM FOR COPPER NANOPARTICLE SINTERING IN HETEROGENEOUS INTEGRATION APPLICATION

Boyao Zhang, Jia Wei, Amarante J. Böttger, Henk W. van Zeij, Pasqualina M. Sarro, and Guoqi Zhang
Delft University of Technology, THE NETHERLANDS

We report the design, fabrication and experimental investigation of a MEMS micro-hotplate (MHP) for fast time-resolved X-ray diffraction (TRXRD) study of Cu nanoparticle paste sintering process. A TRXRD study of nanoCu paste sintering was done using this device. At 1 sec interval, Cu8O reduction and Cu crystallization in sintering is observed.

W3P.078 MICRO HEAT SINK STRUCTURE WITH HIGH THERMAL CONDUCTIVE COMPOSITE VIA MICROMACHINING PROCESS

Yongpeng Wu, Liyan Lai, Yan Wang, Zhuoqing Yang, Hong Wang, and Guifu Ding
Shanghai Jiao Tong University, CHINA

We develop a novel micro heat sink structure integrated with high thermal conductive Cu-diamond composite via micromachining process. The thermal conductivity of Cu-diamond composites are 450.21 W/m K with 325/400 diamond and 614.87 W/m K with 140/170 diamond, respectively, stemming to the perfect interfaces between diamond and copper.

W3P.079 MULTI-HYDROGEL 4D PRINTING FOR DEFORMATION CONTROL

Takuya Uchida and Hiroaki Onoe
Keio University, JAPAN

We propose a method to fabricate three-dimensional microstructures composed of multiple types of stimuli-responsive hydrogels. Printing multiple types of stimuli-responsive hydrogels, printed multi-material hydrogel structures realize controllable deformation. Our proposed method would be an effective tool for creating multi-hydrogel 3D microstructures with various types of stimuli (optical, pH, molecular, etc.), for applications in soft actuators/robotics, and self-assembly/adaptive systems.

W3P.080 NANONEEDLE-ELECTRODE ARRAY PACKAGED WITH AMPLIFIERS FOR RECORDING BIOLOGICAL-SIGNALS WITH A HIGH VOLTAGE GAIN

Shuhei Tsuruhara[1], Yoshihiro Kubota[1], Hiroshi Kubo[1], Hirohito Sawahata[2], Shota Yamagiwa[1], Shinnosuke Idogawa[1], and Takeshi Kawano[1]
[1]Toyohashi University of Technology, JAPAN and
[2]National Institute of Advanced Industrial Science and Technology, JAPAN

The challenge of nano-scale electrode in the nano-scale recording of biological signal is to realize the recording capability without voltage attenuation, which is due to the electrode's high impedance characteristics. To solve the issue of nanoelectrode, here we propose a package of amplifier modules of source follower to the nano electrode. The proposed package technique is very simple, offering nano-scale recording of biological signals with a high voltage gain.

W3P.081 PDMS-BASED DUAL-CHANNEL PNUEMATIC MICROACTUATOR USING SACRIFICIAL MOLDING FABRICATION TECHNIQUE

Tariq Rehman[1], Ahmad Athif Faudzi[1], Marwan Nafea[2] and Mohamed Sultan Mohamed Ali[1]
[1]Universiti Teknologi, MALAYSIA and [2]University of Nottingham, MALAYSIA

This paper presents a novel PDMS based dual-channel bellows-structured pneumatic actuator, fabricated through sacrificial molding technique. Experimental results have shown that the developed actuator is able to achieve bi-directional bending motion against low input pressure. Bidirectional bending angle of up to 60° with force of 0.18 N at input pressure of 100 kPa were recorded. This invention is expected push the boundaries of soft robotics towards more flexible robotic surgical tools.

W3P.082 STRETCHABLE WAVY PIEZOELECTRIC SENSOR FABRICATED BY MICRO-CORRUGATION PROCESS

Michitaka Yamamoto, Kazuki Hiraoka, Seiichi Takamatsu, and Toshihiro Itoh
University of Tokyo, JAPAN

We developed micro-corrugation process to form vertically wavy thin film piezoelectric sensor for highly stretchable human motion sensors. Previous fabrication process to make vertical wavy with prestretch rubber is ununiform but our micro-corrugation process of bending films with gears defines the wave structure by the pitch of the gear. Micro wavy strain sensor with 600 μm pitch and 140 μm height sustains 15 % strain. Our sensor succeeded to detect the bending motion of human finger.

W3P.083 TIME AND COST EFFECTIVE FABRICATION OF STRETCHABLE MICRO-SUPERCAPACITOR PATCHES USING A VINYL CUTTER

Renxiao Xu[1], Yuanyuan Huang[1], Peisheng He[1], Pinghsun Lee[1], Mohan Sanghadasa[2], and Liwei Lin[1]
[1]Univeristy of California, Berkeley, USA and [2]US Army, USA

We use a desktop-size vinyl cutter as the fabrication platform for stretchable microsupercapacitorpatches with interdigital patterns. Compared with lithography-based methods, our method can greatly reduce cost and time (by ~70%). Patterns and patch outlines were defined by automated cutting blades at sufficient resolution (smallest feature ~100μm). This fabrication method yields stretchable patches with good capacitor performances and sufficient mechanical stretchability.

W3P.084 TRANSPARENT PZT MIM CAPACITORS ON GLASS FOR PIEZOELECTRIC TRANSDUCER APPLICATIONS

Gwenael Le Rhun, Christel Dieppedale, Baba Wague, Corentin Querne, Gregory Enyedi, Pierre Perreau, Pierre Montmeat, Christophe Licitra, and Stephane Fanget
University of Grenoble, Alpes, CEA-LETI, FRANCE

We fabricated fully transparent PZT based MIM capacitor on glass substrate for piezoelectric transducer applications. PZT film, grown on 200 mm Si substrate, was reported on glass. ITO/PZT/ITO capacitors show excellent ferroelectric properties, thus proving piezoelectric behavior. This first demonstration opens the way to the integration of transparent piezoelectric actuators on glass such as for haptic devices.

W3P.085 UNIQUE METHOD OF SI LENSES FABRICATION FOR WAFER LEVEL PACKAGING

Amit Kulkarni, Norman Laske, Pauline Malaurie, and Ralf Dudde
Fraunhofer ISIT, GERMANY

This paper presents a novel technology platform to fabricate Si lenses on wafer level by using pre-manufactured Si spheres. Instead of fabricating lenses with the required focal length or Radius of Curvature (ROC) directly; Si spheres with the required ROC are pre-selected, positioned and embedded in either glass or Si which can form a cap wafer for wafer level integration of IR sensors.

M3P.084 A 0.1μM-RESOUTION SILICON TACTILE SENSOR WITH PRECISELY DESIGNED PIEZORESITVE SENSING STRUCTURE

Tsubasa Nakashima, Kazuki Watatani, Kyohei Terao, Fusao Shimokawa, and Hidekuni Takao
Kagawa University, JAPAN

In this paper, a newly developed ultra-high resolution tactile sensor with a spatial resolution of 0.1μm and a force resolution of 120μN is reported for the first time. The new device in this study has realized 6 times higher performance in spatial resolution and 20 times higher performance in force resolution than the tactile sensor device previously reported. The measured surface shape corresponded well to the actual surface shape in sub-micron region.

M3P.085 A FINGERTIP-SHAPED TACTILE SENSOR WITH MACHINE-LEARNING-BASED SENSOR-TO-INFORMATION PROCESSING

Jan Kuehn[1] and Yiannos Manoli[1,2]
[1]University of Freiburg, GERMANY and [2]Hahn Schickard, GERMAY

We present a fingertip-shaped tactile sensor with machine learning-based signal processing. Contributions include: (1) sensing static forces and slip vibrations with the same sensor type; (2) simple design based on a fully integrated stress sensor ASIC; (3) learning-based sensor-to-information processing that is fast and has a small footprint. The results show that the sensor can classify abstract information, like the direction of applied forces, with 99.8% accuracy.

M3P.086 A MODE-LOCALIZED LORENTZ FORCE MAGNETOMETER WITH RESOLUTION OF 1.6μT/√ HZ

Zimu Yan, Yongcun Hao, Wenmu Li, Zhao Zhang and Honglong Chang
Northwestern Polytechnical Univerisity, CHINA

This paper for the first time reports a resonant magnetometer based on the mode localization phenomenon. We use the amplitude ratio as the readout metric, and resolution of the magnetometer reaches 1.6μT/√ Hz in the range of 90mT.

M3P.087 A NOVEL MEMS 3-AXIS THERMAL ACCELEROMETER WITH 5-WIRE STRUCTURE USING PLANAR STACKING METHOD

Zhe Li, Wenhan Chang, Shoule Sun, Chengchen Gao, and Yilong Hao
Peking University, CHINA

We propose a novel MEMS 3-axis thermal accelerometer for the first time. Two five-wire structures perpendicular to each other are fabricated using planar stacking method. Compared with other 3-axis thermal accelerometers, this accelerometer has simpler fabrication process and signal processing circuit, and the sensitive directions are strictly orthogonal with almost the same sensitivities. For one five-wire structure, the sensitivities of the two orthogonal directions are 16.1mV/g and 18.4mV/g.

M3P.088 A NOVEL QCM MASS SENSING SYSTEM INCORPORATED WITH A 3-DOF MODE LOCALIZED COUPLED RESONATOR STIFFNESS SENSOR

Yuan Wang[1], Chen Wang[1], Chun Zhao[2], Huafeng Liu[2], Delphine Cerica[1], Mathieu Baijot[3], François Dupont[1], Serguei Stoukatch[1], and Michael Kraft[3]
[1]University of Liege, BELGIUM, [2]Huazhong University of Science & Technology, CHINA, and [3]University of Leuven (KU Leuven), BELGIUM

This work reports on a QCM mass sensor under atmospheric pressure is combined with a 3-DOF micromachined coupled resonator in vacuum. A novel mass to stiffness transduction mechanism is achieved. The results demonstrate that a 3-DOF mode localized coupled resonator incorporated with a QCM mass sensor has potential to be employed as a direct liquid contact biochemical transducer.

M3P.089 AN AMBIENT TEMPERATURE COMPENSATED MICROTHERMAL CONVECTIVE ACCELEROMETER WITH HIGH SENSITIVITY STABILITY

Xiaoyi Wang[1], Wei Xu[2], Izhar[1], and Yi-Kuen Lee[1]
[1]Hong Kong University of Science and Technology, HONG KONG and [2]Shenzhen University, CHINA

For the first time, we reported both theoretical and experimental analysis on the ambient temperature effect on the sensitivity of MTCA. Our work reveals that the sensitivity variations not only affected by the thermofluid properties but also relevant to redistributed temperature field in the enclosing chamber. The sensitivity attenuation function is precisely predicted by the 1D model, which could be applied for effectively compensating the sensitivity drifting from 65% to 1.84%.

M3P.090 AUTOMATED FREQUENCY AND QUALITY FACTOR MISMATCH COMPENSATION METHOD FOR MEMS RATE INTEGRATING GYROSCOPE

Takashiro Tsukamoto and Shuji Tanaka
Tohoku University, JAPAN

This paper reports a method to automatically compensate the frequency and Q-factor mismatch in a rate integrating gyroscope (RIG). The proposed method detects the cross-coupling terms, which comes from the frequency and Q-factor mismatches, and tunes the driving signals to compensate these mismatches. The proposed method was experimentally confirmed. Using this method, the cross-coupling terms could be 3 orders of magnitudes smaller than the non-compensated state.

M3P.091 CMOS-MEMS TRI-AXIAL PIEZO-RESISTIVE TACTILE SENSOR WITH MONOLITHICALLY/ VERTICALLY INTEGRATED INDUCTIVE PROXIMITY SENSOR

Jia-Horng Lee, Sheng-Kai Yeh, and Weileun Fang
National Tsing Hua University, TAIWAN

This study demonstrates a novel tri-axial piezo-resistive tactile sensor vertically integrated with inductive proximity sensor using standard CMOS process. The three merits: (1) tri-axial tactile sensing unit and proximity sensing unit can be vertically integrated on one chip, (2) normal and shear loads can be detected by four discrete piezo-resistive sensing elements, (3) footprint reduction of chip due to the vertical integration of sensing elements.

M3P.092 DESIGN AND CHARACTERIZATION OF ACOUSTIC PARTICLE VELOCITY SENSORS FABRICATED WITH A COMMERCIAL POST-CMOS MEMS PROCESS

Massimo Piotto[1], Andrea Ria[1], Domenico Stanzial[2], and Paolo Bruschi[1]
[1]University of Pisa, ITALY and [2]CNR-IMM, ITALY

We have designed acoustic particle velocity sensors based on MEMS structures that exploit a thermal principle to detect the local fluid displacement. The main novelty with respect to previous work is the use of a commercially available post-CMOS micromachining process for the whole fabrication flow. We present the experimental characterization of the sensors focusing on sensitivity and bandwidth aspects. Comparison with the simulated data are also analyzed.

M3P.093 EFFECT OF SUBSTRATE THICKNESS ON ANCHOR DAMPING IN MEMS DEVICES

Gabrielle D. Vukasin[1], Veronica K. Sanchez[1], Christopher P Cameron[1], Hyun-Keun Kwon[1], Janna Rodriguez[2], Ian B. Flader[3], Yunhan Chen[4], and Thomas W. Kenny[1]
[1]Stanford University, USA, [2]Intel, USA, [3]Invensense, USA and [4]Apple Inc., USA

We analyze the effect of thinning the substrate of an encapsulated MEMS resonator on anchor damping. We found that thinning the die decreases anchor damping as long as the encapsulated die is not stressed by silver paste or some adhesive.

M3P.094 ENHANCING PARAMETRIC SENSITIVITY USING MICRO-LEVER COUPLER IN MECHANICAL COUPLING MODE-LOCALIZED MEMS ACCELEROMETER

Wang Zheng, Xingyin Xiong, Zhitian Li, Kunfeng Wang, Wuhao Yang, and Xudong Zou
Chinese Academy of Sciences (CAS), CHINA

This paper reports a mode-localized resonant accelerometer(ML-RXL) with novel designed micro-lever mechanical coupler to significantly enhance its parametric sensitivity. The experiment results demonstrate the sensitivity of prototype is 17.265 AR/g in the linear operating region, which is one order of magnitude higher than prior work and paves the way for ML-RXL to achieve the sub-g resolution.

M3P.095 EXPERIMENTS AND SOLUTION OF ASYMMETRY EFFECT FOR MEMS THERMAL WIND SENSOR

Run Tian[1], Zhenxiang Yi[1], Lei Han[1], Ming Qin[1], Qing-An Huang[1], and Kewen Long[2]
[1]Southeast University, CHINA and [2]Foshan Chuandong Magnetic Electronic Co., Ltd., CHINA

For micro-electro-mechanical systems (MEMS) thermal wind sensor based on calorimetric principle, asymmetry effect, rarely reported in literature, exerts significant influence upon the performance. In this paper, for the first time, experiments are performed to investigate this phenomenon. In order to optimize the direction dependence of the sensor caused by asymmetry effect, thermal loss method is used to reduce the error of the speed measurement.

M3P.096 FABRICATION AND EVALUATION OF TACTILE PINS FOR PASSIVE TYPE TACTILE DISPLAYS USING HIGH FORMABILITY SHAPE MEMORY ALLOYS

Keita Nambara, Keiichirou Iki, Chiemi Oka, Seiichi Hata, and Junpei Sakurai
Nagoya University, JAPAN

We fabricated and evaluated of tactile pins for passive type tactile displays using Ti-Ni-Cu high formable shape memory alloys (SMAs). They were fabricated by utilizing viscos flow of metallic glasses of Ti-Ni-Cu. After crystallization, they turned to SMAs and were driven by superelasticity. As the results, we succeeded in acquiring the desired three-dimensional structure and measuring reaction force of 20 mN or more. Also, we succeeded in changing reaction force by temperature control.

M3P.097 GEOMETRIC COMPENSATION OF (100) SCS VIBRATING RING GYROSCOPE FOR MODE-MATCHING ACHIEVING HIGH IMMUNITY TO FABRICATION IMPERFECTIONS

Zesen Bai, Jian Cui, Qiancheng Zhao, Yinpeng Wang, and Zhenchuan Yang
Peking University, CHINA

A MEMS resonating ring gyroscope with the cascaded rectangular beam as supporting spring fabricated by (100) SCS was proposed. This design can geometrically compensate the frequency split due to the anisotropic of Young's modulus of (100) SCS, improve the gyroscope's immunity to fabrication imperfections, and easy to realize single chip CMOS integration. The results show that the design reduce the frequency split to the level of isotropic materials and achieve good manufacturing repeatability.

M3P.098 HERMETICITY OF $SI_{1-x}GE_x$ DIAPHRAGMS FOR THE FABRICATION OF A CAPACITIVE POST-CMOS PRESSURE SENSOR

Christian Walk[1], Alexander Netaev[1], Matthias Wiemann[1], Michael Görtz[1], Holger Vogt[1], Wilfried Mokwa[2], and Karsten Seidl[1,3]
[1]Fraunhofer IMS, GERMANY, [2]RWTH Aachen University, GERMANY, and [3]University of Duisburg-Essen, GERMANY

This paper presents post-CMOS compatible, hermetically sealed SiGe diaphragms fabricated in surface micromachining, which will allow for monolithic integration of a MEMS capacitive pressure sensor on top of any CMOS substrate. Innovative claims include (1) a complete filling of vertically arranged etch access holes, (2) a tuneable selective growth on a released SiGe diaphragm with minimised deposition inside the sensor cavity,(3) minimised intrinsic stress and (4) He-diffusion.

M3P.099 HIGH SENSITIVITY SURFACE ACOUSTIC WAVE STRAIN SENSOR BASED ON PMN-PT THICK FILM

Qing Li, Lijun Lu, Yingwei Tian, Zhiran Yi, Jingquan Liu, and Bin Yang
Shanghai Jiao Tong University, CHINA

We developed a flexible surface acoustic wave (SAW) strain sensor based on PMN-PT thick film on stainless steel substrate with high sensitivity of 1160.46 Hz/ε. The dimension of this device is 6.58 mm x 4.19 mm x 60 Em. This sensor can be widely used in instrument measurement, mechanical body inspection, aerospace fields.

M3P.100 HIGH-ENERGY DENSITY MICRO-MACHINED CELLULAR ARRAYS OF ELECTROSTATIC ACTUATORS

Amin Abbasalipour, Prithviraj Palit, and Siavash Pourkamali
University of Texas, Dallas, USA

This work presents micro-machined electrostatic actuator arrays producing relatively large forces and wide displacement ranges. The actuators are comprised of flexible silicon skeleton with a network of trench refilling polysilicon electrodes electrically insulated from the silicon walls by submicron air-gaps. The array architecture provides large displacement by adding displacements from individual cells, while submicron gaps lead to relatively large actuation forces.

M3P.101 HIGHLY SENSITIVE DETECTION OF FINE ELECTROSTATIC ATTRACTION BY RESONANCE-DRIVEN SILICON-HAIR DEVICE

Kohki Hamamoto[1], Yusaku Maeda[1,2], Kyohei Terao[1], Fusao Shimokawa[1], Fumikazu Oohira[1,3], and Hidekuni Takao[1]
[1]Kagawa University, JAPAN, [2]National Institute of Technology, Kagawa, JAPAN, and
[3]Open University of Japan, JAPAN

This paper reports highly sensitive detection of fine electrostatic attraction using resonance-driven silicon-hair device. The device has a fine silicon-hair with 10 μm width and 5 mm length, and it independently detects 2-axis force and 1-axis moment applied to itself. In the experiments, the minimum sensitivity of electrostatic attraction have reached to 0.1μN . Resolution of force and moment detectors have been improved by tenfold using the resonance-drive of silicon-hair.

M3P.102 IN-SITU MEASUREMENT OF STRESS IN THIN FILMS USING MICROMACHINED QUARTZ RESONATORS

Nishit Goel[1] and Srinivas Tadigadapa[2]
[1]Invensense-TDK Inc., USA, and [2]Northeastern University, USA

Micromachined AT-cut quartz cantilever resonators are demonstrated for in-situ measurement of stress in thin films during their deposition. However, the frequency shift due to stress is conflated with that due to mass deposition. A method to compensate for mass based frequency shift is reported and used for the in-situ measurement of stress during ion-beam deposition of tungsten. Stress sensitivity for a 161 MHz resonator is found to be 0.995 kHz/MPa.

M3P.103 INTEGRATION OF STAINLESS-STEEL TACTILE BUMP WITH INDUCTIVE TACTILE SENSOR ARRAY FOR 3D MICRO JOYSTICK-BUTTON APPLICATION

Sheng-Kai Yeh and Weileun Fang
National Tsing Hua University, TAIWAN

This study presents a novel inductive tactile sensor array with rigid stainless-steel bump sensing interface for 3D micro joystick-button application. The merits: (1) batch process to define and etch bumps on stainless-steel sheet, (2) compact sensing coil array using CMOS platform can distinguish the magnitude and distribution of tactile loads, and (3) polymer as spring and encapsulation layer to cover the rigid tactile bump and CMOS chip without any fragile suspended thin film structure.

M3P.104 MASS SENSITIVITY MEASUREMENTS OF A NOVEL HIGH Q-FACTOR DISK RESONATOR FOR LIQUID-PHASE SENSING APPLICATIONS

Habiba Begum, Abid Ali, and Joshua En-Yuan Lee
City University of Hong Kong, HONG KONG

We present, for the first-time, mass sensitivity of novel resonant mode based on disk resonator that delivers the highest Q-factor among resonators tested in liquid (Q-362). The mode of interest is referred as the Button-like (BL) mode. The high Q-factor of the BL mode enhances mass resolution. Its Rm in water is 5.3kΩ, which eases the difficulty on designing control circuit. The resonator has a measured mass sensitivity of 53.8ppm/ng for uniformly deposited mass on the resonator's surface.

M3P.105 MICROACOUSTIC SENSORS WITH INTEGRATED CARBON NANOTUBES FOR HIGH VOC SENSITIVITY

Teona Mirea, Jimena Olivares, and Marta Clement
Universidad Politécnica de Madrid, SPAIN

We present a solidly mounted resonator with integrated carbon nanotube (CNTs) forest, possessing a high sensitivity towards VOCs. With the same device we demonstrate how much CNTs increase this mass sensitivity independently of the resonant frequency value.

M3P.106 MONOLITHIC SILICON-ON-NOTHING FIBER-BASED PRESSURE SENSORS

Simon Lorenzo, Yu-Po Wong, and Olav Solgaard
Stanford University, USA

Monolithic-silicon fiber-based pressure sensors offer high resolution over a broad frequency range with minimal footprint. We fabricate these devices using scalable single-mask silicon nanofabrication. Our sensors consist of a sealed 1 μm cavity under a 1 μm thick silicon diaphragm only 100 μm in diameter. For static pressures from 0.3 to 1.4 atm, our sensors showed a standard deviation of 2.6×10^{-3} atm. Our sensors have a pressure resolution of 1.0×10^{-6} atm/√hz out to 10 kHz.

M3P.107 NONLINEARITY OF DEGENERATELY DOPED FLEXURAL MODE SILICON MICROMECHANICAL RESONATORS

Saisneha Koppaka[1], Anne L. Alter[1], Gabrielle D. Vukasin[1], Dongsuk D. Shin[1], Ian B. Flander[1], Yunhan Chen[2], and Thomas W. Kenny[1]
[1]Stanford University, USA and [2]Apple Inc., USA

We present an experimental study of nonlinearities in degenerately doped silicon micromechanical resonators operating in the flexural mode. Double-ended tuning forks in two geometries and two wafer orientations are used to analyze the elastic effects of p-type and n-type doping. Closed-loop frequency sweeps characterize the amplitude-frequency response of each system.

M3P.108 ON FRESNEL-BASED SINGLE AND MULTI SPECTRAL SENSORS FOR INSECTS' WINGBEAT RECORDING

Ilyas Potamitis[1], Iraklis Rigakis[2], and Nicolaos-Alexandros Tatlas[2]
[1]Technological Educational Institute of Crete, GREECE and [2]University of West Attica, GREECE

We present a novel, low-cost, optical sensor of insects' wingbeat and its associated recorder that aims to extract a deeper representational signal of the wingbeat event and color characterization of the main body of the insect, namely: A) We record the backscattered light that is richer in harmonics than the extinction light; B) We use three different spectral bands, i.e. a multispectral approach that aims to grasp the melanisation and microstructural and color features of the wing and body.

M3P.109 PIEZOELECTRIC MICROMACHINED ACOUSTIC TRANSDUCER WITH ELECTRICALLY-TUNABLE RESONANT FREQUENCY

Alessandro Nastro[1], Libor Rufer[2], Marco Ferrari[1], Skandar Basrour[2], and Vittorio Ferrari[1]
[1]University of Brescia, ITALY and [2]Université Grenoble, Alpes, FRANCE

A Piezoelectric MEMS acoustic transducer able to electrically tune the resonant frequency in receiver and transmitter modes is reported. The proposed 6x6mm squared diaphragm has been simulated, fabricated, and measured. A DC bias voltage applied to the piezoelectric layer produces a controllable stress, thus leading to a matching of the series and parallel resonant frequencies. This allows to increase performances when the transducer is operated as both transmitter and receiver.

M3P.110 ROBUST AND FLEXIBLE THERMAL SENSOR USING THE 3-OMEGA-METHOD TO INVESTIGATE THERMAL PROPERTIES OF FLUIDS

Ralf E. Bernhardsgrütter[1,3], Christoph J. Hepp[1], Katrin Schmitt[2,3], Martin Jägle[2], Hans F. Pernau[2], and Jürgen Wöllenstein[2,3]
[1]Innovative Sensor Technology IST AG, SWITZERLAND, [2]Fraunhofer Institute for Physical Measurement Techniques, GERMANY, and [3]University of Freiburg, GERMANY

This paper presents a platinum thin film sensor able to investigate the thermal properties of a fluid whereas the sensing element is protected against corrosion by an intermediate stainless-steel wall. Progress claims include: 1) the 3-omega method is applied to investigate fluids which are not directly adjacent to the sensitive layer, 2) the 3-omega-method is applied for a meander structure, 3) a theoretical model is developed and agrees well with the experiment.

M3P.111 SELF-HEATED THERMORESISTIVE FLOW SENSOR COATED WITH PARALENE-C FOR RELIABILITY ENHANCEMENT BY USING 0.35μM CMOS MEMS TECHNOLOGY

Wei Xu[1], Xiaoyi Wang[2], Basant Mousa[2], Maria Paszkiewicz[2,3], and Yi-Kuen Lee[2]
[1]Shenzhen University, CHINA, [2]Hong Kong University of Science and Technology, HONG KONG, and [3]Karlsruhe Institute of Technology (KIT), GERMANY

A Self-Heated Thermoresistive Flow sensor with Paralene-C coating is reported by using a CMOS MEMS technology. For N2 flow, the sensor achieves the normalized sensitivity of 171mV/(m/s)/W, while keeps a low power of 18.3mW. Besides, the achieved accuracy of ±0.04m/s within the range of 0~2.5m/s, enabling this robust sensor (more than 9 years of working time) for indoor airflow measurement even in the moist condition. Therefore, this sensor will be a promising flow device for smart buildings.

M3P.112 SPATIALLY-RESOLVED 3Ω THERMAL FLOW SENSING FOR MICROFLUIDICS AND BIOLOGY

Claude Meffan[1], Nicolas Cheradame[1], Mathieu Sellier[1], Emilio P. Calius[2], and Volker Nock[1]
[1]University of Canterbury, NEW ZEALAND and [2]Callaghan Innovation, NEW ZEALAND

We present the integration of a 3ω single resistive element into a microfluidic channel for use as a flow sensor and introduce the concept of finite thermal penetration depth as a means to probe fluid flow with spatial resolution. Two parallel microfluidic channels separated by a membrane are used to demonstrate the sensors' capability to resolve flow at a distance and through solid obstacles, making it suitable for study of mass flow in complex biological environments.

M3P.113 SURFACE ACOUSTIC WAVE GENERATION AND PROPAGATION ON POLAR GLASS-CERAMIC FOR HIGH TEMPERATURE SENSORS

Florian Dupla[1], Marie-Sophie Renoirt[1], Maurice Gonon[1], Nikolay Smagin[2], Marc Duquennoy[2], Grégory Martic[3], and Mohamed Rguiti[4]
[1]University of Mons, BELGIUM, [2]IEMN-DOAE UPHF, FRANCE, [3]CRIBC INISMA, FRANCE, and [4]LMCPA UPHF, FRANCE

We present a surface acoustic wave (SAW) device able to operate at 800°C. It is based on a piezoelectric glass-ceramic substrate obtained by surface crystallization. The deposition of the electrodes is mastered. The glass-ceramic ability to generate and propagate SAW at high temperature is evaluated through thermomechanical analyses and evidenced using a prototype device. The architecture of a high temperature pressure device based on this material is presented.

M3P.114 TACTILE SENSOR USING MICROCANTILEVER EMBEDDED IN FLUOROPOLYMER FOR WATER AND ETHANOL RESISTANCE

Takumi Takahashi[1], Shuhei Sato[1], Takashi Abe[1], Haruo Noma[2], and Masayuki Sohgawa[1]
[1]Niigata University, JAPAN and [2]Ritsumeikan University, JAPAN

We have employed fluoropolymer as novel elastomer material instead of PDMS for the MEMS tactile sensor and demonstrated its high resistances to both water and ethanol. Tactile sensor using fluoroelastomer can detect force in water and ethanol just as in air. Fluoroelastomer employed in this study can be expected to be used in various applications not only for tactile sensor but also for other MEMS sensors used in solvent such as chemical or biological sensors.

M3P.115 TEMPLATED SELF-ASSEMBLY OF MICROCOMPONENTS USING WATER-OIL INTERFACE

Ryo Hamano and Hiroaoki Suzuki
Chuo University, JAPAN

We report a method of constructing an integrated structure of microcomponents using water/oil (W/O) interface as a template. W/O interfaces are used to adsorb colloidal particles for self-assembly. However, in conventional bulk-based methods, there has been no precise control on the size and shape of the particle assembly. We tested the use of a template structure to define the size and shape of the W/O interface for assembly of microparticles and photofabricated microcomponents.

M3P.116 TOWARDS 3-AXIS FM MEMS GYROSCOPES: MECHANICAL DESIGN AND EXPERIMENTAL VALIDATION

Valentina Zega[1], Claudia Comi[1], Elia Bordiga[1], Giacomo Langfelder[1], Luca G. Falorni[2], and Alberto Corigliano[1]
[1]Politecnico di Milano, ITALY and [2]STMicroelectronics, ITALY

Frequency Modulation (FM) has been studied as an innovative working principle for MEMS gyroscopes and as a smart solution for the scale factor stability against environmental fluctuations. We propose three tuning-fork structures for a yaw, pitch and monolithic 3-axis FM gyroscope. Preliminary measurements of the scale factors of the three FM gyroscopes prove the expected behavior of the devices. In particular, we show the first experimental proof of a monolithic 3-axis FM gyroscope.

Tuesday - Mechanical/Physical Sensors and Microsystems

T3P.085 A BIOINSPIRED PIEZOELECTRIC CILIA ARRAY FOR SENSING OF HYDRODYNAMIC FLOW

Le-Giang Tran, Dong-Hyun Joo, and Woo-Tae Park
Seoul National University of Science and Technology, KOREA

This paper presents a self-powered flow sensor that targeted maneuvering of the UUVs. The fabrication process was taking the advantage of the thermoplastic material. A piezoelectric compound of BaTiO3, MWCNT and EVA was used to replicate the cilia structure from a PDMS mold. The fabricated flow sensor comprised of an array of piezoelectric cilia structures. Experimental data indicated that the generated Vrms increase from 1.8 mV to 2.7 mV when the sensor is subjected to the air flow.

T3P.086 A DISPOSIBLE ARRAY CHIP USING TEMPERATURE-RESPONSIVE COLOR CHANGE TO RECORD TEMPERATURE HISTORY IN TERMINAL COLD CHAIN TRANSPORTATION

Fengyi Zheng and Zhihong Li
Peking University, CHINA

We present a low-cost disposable array chip, which can record the temperature history in the terminal cold chain transportation. A novel approach, temperature-responsive color change, utilizing the frozen layer of mixed water and ethanol with different ratios to control the temperature of color -change reaction, has been proposed to achieve irreversible temperature recording.

T3P.087 A FRONT-SIDE MICRO-FABRICATED TINY-SIZE THERMORESISTIVE GAS FLOW SENSOR WITH LOW COST, HIGH SENSITIVITY, AND QUICK RESPONSE

Dan Xue, Wei Zhou, Zao Ni, Jiachou Wang, and Xinxin Li
Chinese Academy of Sciences (CAS), CHINA

A thermoresistive gas flow sensor is fabricated only from the front-side of (111) silicon wafer for high-yield and low-cost volume production. With the single-wafer-based single-side fabrication process and the optimal thermal-insulation configuration, the flow sensors achieve a tiny size of 0.7mm_0.7mm, ultra-high normalized sensitivity of 3.9mV/(SLM)/mW for nitrogen gas flow, which is 17-fold higher than that of the reported MEMS thermoresistive flow sensor, and short response time of 1.5ms.

T3P.088 A NEW SIMPLE FABRICATION METHOD FOR SILICON NANOWIRE-BASED ACCELEROMETERS

Taeyup Kim[1], Seohyeong Jang[1], Bobaro Chang[1], Jinwoo Sung[1], Seunghyun Lee[1], Hyoungho Ko[2], Kyo-in Koo[3], and Dong-il D. Cho[1]
[1]Seoul National University, KOREA, [2]Chungnam National University, KOREA, and [3]University of Ulsan, KOREA

This paper presents a new fabrication method for silicon nanowires (SiNWs) and its application to accelerometers. The developed process has much reduced fabrication complexity when compared to previous methods by reducing the number of mask layers. Furthermore, the developed method enables monolithic integration of SiNWs with sensing structures and allows controlling the dimensions of SiNWs and sensor structures independently. The developed method can be applied to a plethora of SiNW-based MEMS physical, chemical and optical sensors.

T3P.089 A NOVEL OUT-OF-PLANE ELECTROTHERMAL BISTABLE MICROACTUATOR

Liang Zhou and Huikai Xie
University of Florida, USA

We develop a novel out-of-plane bistableelectrothermal microactuator that is comprised ofinverted-series-connected (ISC) Cu/W bimorphs. TheISC Cu/W bimorphs have been previously employedfor generating large vertical displacement via jouleheating. In this work, the ISC bimorph actuators havebeen engineered into a warped shape via pre-stressedW and unbalanced SiO_2 encapsulation layers to achievelarge bistability of 25μm vertical displacement.

T3P.090 A PIEZOELECTRIC RESONANT HUMIDITY SENSOR WITH ENHANCED SENSITIVITY BASED ON HIGH MODE DRIVEN BY INTERDIGITAL TRANSDUCERS COATED WITH UNIFORM GRAPHENE OXIDE FILM

Jintao Pang, Xianhao Le, and Jin Xie
Zhejiang University, CHINA

This paper reports a high performance humidity sensor using high mode of piezoelectric resonator driven by interdigital transducers (IDT). Innovative claims include: (1) the higher relative sensitivity using high mode driven by IDT compared with normal configuration. (2)monitoring of humidity variation with short response/recovery time.

T3P.091 ANGULAR RATE SENSING BY CIRCULATORY VORTEX FLOW: DESIGN, SIMULATION AND EXPERIMENT

Hoa Thanh Phan[1], Thien Xuan Dinh[3], Canh-Dung Tran[4], Trinh Chu Duc[1],Tung Thanh Bui[2], Phuc Hong Pham[1], and Van Thanh Dau[5]
[1]Hanoi University of Industry, VIETNAM, [2]VNU University of Engineering and Technology, VIETNAM, [3]Ritsumeikan University, JAPAN, [4]University of Southern Queensland, AUSTRALIA, and [5]Griffith University, AUSTRALIA

A fully packaged convective vortex gyrometer actuated by a PZT diaphragm is reported. The flow circulates at higher velocity after each actuating circle to form a vortex in a desired chamber. The angular rate sensing of device is successfully tested using a turntable. The technique is a potential solution to various applications related to inertial sensing and fluidic amplifier.

T3P.092 BIO-INSIPRED FLOW SENSOR USING 3-D GRAPHENE AEROGEL SPHERES

Renwei Mao, Weiquan Yao, Yang Xu, Weiqiu Chen, and Huan Hu
Zhejiang University, CHINA

This paper presents the design, fabrication and characterization of a wind flow sensor using 3-D graphene aerogels as sensing elements. The sensor mimics hair-cell mechanical receptors widely found in nature. This work is the first demonstration of using 3-D graphene aerogels for building flow sensors. This flow sensor can potentially be used in smart infrastructure monitoring and wind speed measurement.

T3P.093 COMPACT MEMS THERMAL WIND SENSOR USING DUAL POLYSILICON LAYERS WITH IMPROVED ACCURACY

Shang Wang, Zhenxiang Yi, Ming Qin, and Qing-an Huang
Southeast University, CHINA

We propose a compact MEMS thermal wind sensor with dual polysilicon layers for the first time. The novelty of this device is that four heaters and four thermistors are placed vertically instead of lateral arrangement in traditional sensors. This method makes the temperature of the heaters and corresponding thermistors approximately equal when working in the temperature-balanced mode. Fabricated using MEMS techniques, the sensor chip shows an improved measurement accuracy.

T3P.094 DOUBLE FUNCTIONAL PIEZOELECTRIC FILM BASED STRETCHABLE AND FLEXIBLE ACOUSTIC EMISSION SENSOR WITH UNIQUE MAGNETIC REPULSION SENSING ENHANCEMENT AND CONTACT FORCE SELF-DETECTABILITY

Guo-Hua Feng and Cheng-Yen Chiang
National Chung Cheng University, TAIWAN

We develop a novel acoustic emission sensor composed of double piezoelectric-film foils and magnets along with stereolithographic structures. The serpentine-shaped sensor possesses stretchable and flexible properties and can monitor the resonant frequency shift by actuating piezoelectric beam and sensing the symmetrical beam response, which allows the sensor to function as an in-situ force sensor. The superior sensitivity of the sensor also allows detect tiny water droplets hitting on a glass.

T3P.095 ELECTRICAL ONLY CALIBRATION OF BAROMETRIC PRESSURE SENSORS USING MACHINE LEARNING

Hadi Najar
Texas Instruments, Inc., USA

We report a novel, rapid and economical approach to calibrate barometric capacitive pressure sensors via electrical measurement only using a machine learning approach. Conventional calibration approaches that use physical means are time consuming and require specialized equipment. We proposed and experimentally validated an electrical only approach through machine learning to calibrate the pressure sensor over a wide range of pressures.

T3P.096 ESTIMATING THE SURFACE ADHESION FORCE USING PULL-IN/ -OUT HYSTERESIS IN COMB-DRIVE DEVICES

João Mouro[1], Sunil Rana[1], Jamie Reynolds[2], Harold Chong[2], and Dinesh Pamunuwa[1]
[1]University of Bristol, UK and [2]University of Southampton, UK

Surface adhesion forces play a critical role when designing and operating non-volatile NEM relays. A technique to estimate the adhesion force between two surfaces is presented. This method uses the hysteresis in pull-in / -out voltages, measured experimentally, in an electrostatically actuated NEM comb-drive with two physically contacting electrodes. The adhesion force is calculated from the force balance describing the pull-out event, using an experimental and numerical mixed approach.

T3P.097 GAN CURRENT TRANSDUCERS FOR HARSH ENVIRONMENTS

Soroush Faramehr[1], Nebojsa Jankovic[2] and Petar Igic[1]
[1]Coventry University, UK and [2]University of Nis, SERBIA

To push towards improved current measurement solutions, we report on gallium nitride current transducers with wide bandwidth (MHz) and high sensitivity (>14 %/T). Their key manufacturing steps and operation at elevated temperatures are presented. The fabricated sensors deliver compact and low-cost solutions for the control and protection of wide-bandgap power electronics.

T3P.098 GROUND REACTION FORCE SENSING IN MILLIGRAM-SCALE LEGGED MICROROBOTS

Ryan St. Pierre[1], Babak Eslami[2], and Sarah Bergbreiter[1]
[1]Carnegie Mellon University, USA and [2]Widener University, USA

This work uses compliant mechanism design to create a two-axis vision-based force sensor to measure 2-DOF ground reaction forces (GRFs) of legged 1 mg microrobots. The sensor was designed algorithmically to tailor the stiffness matrix and printed using direct laser lithography. The sensor was then integrated into the "ground" of an experimental platform. The sensor deformation was observed visually as the robot steps on it, resolving sub-μN GRFs of microrobots for the first time.

T3P.099 HIGH SENSITIVE MICRO FLEXIBLE THERMAL SENSOR FOR FLOW SEPARATION MEASUREMENTS ON AIRFOIL

Baoyun Sun, Binghe Ma, Jinjun Deng, Jian Luo, Pengbin Wang, Yuchao Yan, Weizheng Yuan, and Chengyu Jiang
Northwestern Polytechnical University, CHINA

A highly sensitive micro flexible thermal sensor was developed to investigate the boundary layer transition and separation over NACA 0012 airfoil. The temperature coefficient of resistance (TCR) is the highest value (over 5000ppm/°C) among the flexible thermal sensors with nickel thermistors. The transition location and stall angle of attack (AOA) were identified successfully by the thermal sensors.

T3P.100 HIGH WITHSTAND VOLTAGE PRESSURE SENSORS BASED ON SILICON STRAIN GAUGES-ON-A-GLASS SUBSTRATE

Joon Hyub Kim[1], Ki Bum Kim[1], Sang Ki Lee[1], Nam Ki Min[1] and Chan won Park[2]
[1]Korea University, KOREA and [2]Kangwon University, KOREA

We presents the design, fabrication, and prototype testing of a high pressure sensor which can provide, for the first time, high withstand voltage(>2 kV) at the chip level, not a packaging structure improvement, without scarifying its performance. This is achieved by a special design of silicon strain gauge, based on bonding silicon to alkali-free glass wafers with a high breakdown voltage. In addition, silicon gauges-on-a- glass chip is easy to use due to the presence of a glass substrate.

T3P.101 HOW TO DEFEAT ELECTRIC NOISE IN MEASUREMENT ACQUISITION USING A MICROMECHANICAL ANALOG-TO-DIGITAL CONVERTER

Philip Schmitt and Martin Hoffmann
Ruhr University Bochum, GERMANY

We introduce a MEMS-based electromechanical analog-to-digital converter, which allows to translate a mechanical displacement directly into an electrical binary code. The design, fabrication and characterization of a linear and a logarithmic 5-bit converter with a resolution of 4 μm is presented. Based on the electromechanical analog-to-digital converter a new method of zero electric noise measurement acquisition is proposed, which is applicable for common surface MEMS-sensors.

T3P.102 IN-SITU SELF-COMPENSATED PT-ITO THIN FILM STRAIN GAGE WITH A NANO LAMINATED STRUCTURE

Shenyong Yang, Congchun Zhang, Zhuoqing Yang, Hong Wang, Xiaolin Zhao and Guifu Ding
Shanghai Jiao Tong University, CHINA

This paper reports a novel temperature compensation method for high temperature strain gages. Nano Pt-ITO thin film with laminated structure adherent to the alumina substrate was fabricated by a general micro fabrication process. The temperature coefficient of resistance (TCR) and piezoresistive response of the thin film strain gage have been measured up to 1200 degrees Celsius. Meanwhile, the gage factor K for the Pt-ITO thin film at 1200 degrees Celsius has also been calculated.

T3P.103 LARGE STRAIN MEASUREMENTS BY VACUUM-PACKAGED MEMS RESONATORS MANUFACTURED ON ULTRATHIN SILICON CHIPS

Luca Belsito, Matteo Ferri, and Alberto Roncaglia
CNR-IMM, ITALY

Silicon resonators fabricated with wafer-level vacuum packaging on 60 μm thick silicon chips are utilized for strain measurements after being glued on steel slabs. The response of the ultrathin sensors in bending tests is compared with the one obtained from resonators manufactured on thick silicon substrates, showing astonishing improvements using the thinned chips, with creep levels below 0.1%, no appreciable hysteresis and strain measurement range extended beyond 850 microstrain.

T3P.104 LOW FREQUENCY SOUND PRESSURE LEVEL IMPROVEMENT OF PIEZOELECTRIC MEMS MICROSPEAKER USING NOVEL SPIRAL SPRING WITH DUAL ELECTRODE

Hsu-Hsiang Cheng[1], Zi-Rong Huang[1], Mingching Wu[2], and Weileun Fang[1]
[1]National Tsing Hua University, TAIWAN and [2]GlobalMEMS Co. LTD, TAIWAN

This study presents a piezoelectric MEMS microspeaker with novel spring design to achieve high SPL at low frequencies. The proposed spiral-spring design has simple stress distribution to ease electrical routings and also increase the net driving output for piezoelectric films. Measurements demonstrate 79.5dB SPL with only $2V_{pp}$ driving voltage and 1 mm^2 diaphragm at 1kHz in a 3cm long canal. Furthermore, 106.8dB SPL is observed with $15V_{pp}$ at 1.85kHz without any structure damage.

T3P.105 MEMS MICRO-PUMP FOR AIR SAMPLING APPLICATION

Oskar Z. Olszewski[1], Jan Kubik[2], and Ruth Houlihan[1]
[1]University College Cork, IRELAND and [2]Analog Devices, Inc., IRELAND

This paper presents a MEMS air micro-pump that can work under two different operation modes. In the first mode the device operates based on the principle of an acoustic standing wave. In the second, its operation is based on the mechanical displacement mode. The measured air flow-rate depends on the operation mode and the driving voltage and extends to 2 and 8 mL/min for the acoustic standing wave and displacement mode, respectively.

T3P.106 MICROFABRICATED MEMBRANES FOR RADIATIVE NEAR FIELD MEASUREMENTS

Olivier Marconot, Ivan Latella, Alexandre Juneau-Fecteau, Julien Sylvestre, and Luc G. Frechette
Université de Sherbrooke, CANADA

We present the elaboration and the thermal characterization of $SiO_2/SiN/SiO_2$ membranes suspended onto a silicon substrate with a sub-micron separation distance. These membranes are dedicated to thermal near field radiation measurements and are relevant for the treatment of thermal information and for the near-field thermophotovoltaic.

T3P.107 MINIATURIZED SOIL SENSOR FOR CONTINUOUS, IN-SITU MONITORING OF SOIL WATER POTENTIAL

Yuncong Chen, Yang Tian, Xinran Wang, and Liang Dong
Iowa State University, USA

We developed a miniature sensor for continuous, long-term monitoring of soil water potential for improving agricultural management practices.

T3P.108 ON-CHIP PRECISION RESIDUAL STRAIN DIAGNOSTIC BASED ON GAP-DEPENDENT ELECTRICAL STIFFNESS

Alper Ozgurluk and Clark T.-C. Nguyen
University of California, Berkeley, USA

An on-chip strain measurement structure is demonstrated that harnesses precision frequency measurement to determine the residual strain in a given structural film with unprecedented accuracy, with measured strains as small as 15MPa corresponding to 2.9nm displacements. The importance of this method manifests in the fact that knowledge of residual strain might be the single most important constraint on the complexity of large mechanical circuits.

T3P.109 BATCH FABRICATION OF MULTILAYER POLYMER CANTILEVERS WITH INTEGRATED HARD TIPS FOR HIGH-SPEED ATOMIC FORCE MICROSCOPY

Nahid Hosseini[1], Matthias Neuenschwander[1], Santiago H. Andany[1], Jonathan D. Adams[2] and Georg E. Fantner[1]
[1]École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND and [2]ETH Zurich, SWITZERLAND

We have developed AFM cantilevers consisting of a polymer core, embedded electronic strain sensors, sandwiched between ultra-thin silicon nitride layers. By making the bulk of the cantilevers out of polymer(which is much softer than conventional AFM cantilever materials), we can design our cantilevers to be thick, yet still soft. This yields an unprecedented force sensitivity increase of one order of magnitude.

T3P.110 ROOM AND CRYOGENIC TEMPERATURE BEHAVIOUR OF MAGNETIC SENSORS BASED ON GAN/SI SINGLE SAW RESONATORS

Alexandra Nicoloiu[1], Florin Ciubotaru[2], Claudia Nastase[1], Adrian Dinescu[1], Sergiu Iordanescu[1], Hasnain Ahmad[2], Philipp Pirro[3], Christoph Adelmann[2], and Alexandru Muller[1]
[1]IMT-Bucharest, ROMANIA, [2]IMEC, BELGIUM, and [3]University of Kaiserslautern, GERMANY

This work analyses resonance frequency shift vs. the applied magnetic field strength for GHz GaN/Si SAW resonators. Magnetostrictive strips were deposited in the proximity and also over the IDTs, after covering them with a BCB layer. Magnetic sensitivity was analysed at room and cryogenic temperatures; measurements proved high values at 16K. The work targets emerging applications of SAW resonators in driving spin wave pumping and in coupling surface acoustic waves with superconducting Q-bits.

T3P.111 SHORTENING BIAS WARM-UP TIME WITH ACTIVE CONTROL OF THE COUPLING STIFFNESS FOR MEMS GYROSCOPES

Jian Cui, Qiancheng Zhao, Yinpeng Wang, and Guizhen Yan
Peking University, CHINA

We develop a closed-loop control of coupling stiffness method to shorten the bias warm-up time of MEMS gyroscopes which is a critical factor for short time-of-flight tactical applications. By restrain the thermal bias drift caused by coupling stiffness, the bias warm-up time is improved with three order of magnitude reduction.

T3P.112 SUB-MICRON MEMS ACCELEROMETER WITH HANDLE-LAYER PATTERNING FOR DAMPING ENHANCEMENT USING TIME TRANSDUCTION

Inês S. Garcia[1,2], Eurico E. Moreira[1,2], Rosana A. Dias[2], João Gaspar[2], Filipe S. Alves[2], and Luis A. Rocha[1,2]
[1]University of Minho, PORTUGAL and [2]International and Iberian Nanotechnology Laboratory (INL), PORTUGAL

A very high resolution SOI-based MEMS accelerometer for geodetic space grade applications using pull-in time measurements is presented. Parallel-plates implemented in the handle-layer are used to provide the necessary squeeze-film damping, while increasing the effective-mass. The large mass devices with low-Q have been fabricated and tested using time transduction. The high measured sensitivity enables the use of the device in ultra-high resolution and low-dynamic range applications.

T3P.113 TEMPERATURE DRIFTS OF THE FLOATING ELEMENT WALL SHEAR STRESS SENSOR WITH CAPACITIVE SENSING

Guanghui Ding, Binghe Ma, Jinjun Deng, Jian Luo, Weizheng Yuan, and Jiahao Yao
Northwestern Polytechnical University, CHINA

To improve the precision of wall shear stress measurements under the boundary layer, we develop the floating element wall shear stress sensor with capacitive sensing, and investigate temperature drifts of the sensor on a temperature-controlled wind tunnel. We initially understand the characterization of the temperature-dependent outputs of the sensor, which is of great value to make temperature compensations for accurate measurements of wall shear stress in practical applications.

T3P.114 THE ELECTROCHEMICAL SEISMOMETER BASED ON A NOVEL DESIGNED SENSING ELECTRODE FOR UNDERSEA EXPLORATION

Chao Xu, Junbo Wang, Deyong Chen, Jian Chen, Bowen Liu, Wenjie Qi, Xichen Zheng, Hua Wei, and Guoqing Zhang
Chinese Academy of Sciences (CAS), CHINA

This paper developed a MEMS based electrochemical seismometer featured with a new structure of sensing electrodes. The proposed seismometer featured with 1) simplification of the device fabrication process and 2) an increase in the device sensitivity. As a proof-of-concept demonstration, the seismometers developed in this study were tested in a sea trial, and shown to function well on a sea bed (e.g. 1000 m in depth) with correlation coefficients between two devices quantified as 0.94.

T3P.115 ULTRA-SENSITIVE OPTO-PIEZORESISTIVE SENSORS UTILISING 3C-SIC/SI HETEROSTRUCTURES

Thanh Nguyen, Toan Dinh, Abu Riduan Md Foisal, Hoang-Phuong Phan, Tuan-Khoa Nguyen, Nam-Trung Nguyen, and Dzung Viet Dao
Griffith University, AUSTRALIA

we report here an ultra-sensitive opto-piezoresistive effect in 3C-SiC nanofilm grown on silicon. The sensitivity of the sensor was significantly enhanced by coupling the photovoltaic effect and controlling distribution of hole/electron in semiconductors. By applying this method, the gauge factor (GF) of strain sensors can be improved at least three orders of magnitude. A GF of approximately 58,000 was observed, which is the highest GF reported for semiconductor piezoresistive sensors to date.

Wednesday - Mechanical/Physical Sensors and Microsystems

W3P.086 A MEMS PRESSURE SENSOR BASED ON DOUBLE- ENDED TUNING FORK RESONATOR WITH ON-CHIP THERMAL COMPENSATION

Dongxiang Han[1], Jian Wang[2], Shenfang Yuan[1], Ting Yang[3], Bihai Chen[2], Gang Teng[2], Wei Luo[2], Yufan Chen[2], Yong Li[2], Mingming Wang[2], Yugang Yin[2], Xiaofeng Jin[2], Shiming Zhang[2], and Jian Feng[2]
[1]Nanjing University of Aeronautics and Astronautics, CHINA, [2]Beijing Research Institute of Telemetry, CHINA, and [3]Tsinghua University, CHINA

We design, simulate, and fabricate a MEMS pressure sensor based on quartz crystal double-ended tuning fork (DETF) resonator with on-chip thermal compensation which is more suitable for pressure measurement in rapidly-changed temperature environment. To improve the timeliness of temperature compensation, the single-ended tuning fork (SETF) resonator for in-situ temperature measurement is used to remove the effects of temperature drift on the DETF resonator.

W3P.087 A NOVEL PHOTOACOUSTIC MICROSENSOR FOR ENHANCED QUALITY FACTOR DETECTION OF LOW CONCENTRATION ANALYTES

Imran Latif, Zhonglie An, Masaya Toda and Takahito Ono
Tohoku University, JAPAN

We present a novel approach to detect minuscule photoacoustic signals in condense mediums which benefits from high quality factor of a vacuum packaged Si resonator. A large detection sensitivity is achieved by tuning the optical excitation at the fundamental resonance mode and through direct acoustic coupling of the packaged device with the sample on the sensing platform.

W3P.088 ACOUSTIC PROPELLER BASED ON AIR JETS FROM ACOUSTIC STREAMING

Yongkui Tang and Eun S. Kim
University of Southern California, USA

We developed acoustic lifter and thruster capable of generating propulsion force on-demand from synthetic air jets generated by acoustic waves passing through orifices on a thin plastic (shaped with laser-machining) covering a sound source (audio speaker). The orifice array pattern was optimized through experiments to produce large thrust force. By varying driving condition and operating frequency, the transducer that weighs 603 mg can rotate, or jump 2.8 mm high and 100 mm far, propelled by the air jets. When tested as an acoustic lifter, the transducer is capable of lifting a plastic piece of 299 mg and rotating a metal piece of 20.4 g. The device could also be driven with acoustic signal instead of electrical power.

W3P.089 AN OVEN-CONTROLLED MEMS OSCILLATOR (OCMO) WITH SUB 10MW, ± 1.5PPB STABILITY OVER TEMPERATURE

Hyun-Keun Kwon[1], Lizmarie Comenencia Ortiz[1], Gabrielle D. Vukasin[1], Yunhan Chen[2], Dongsuk D. Shin[1], and Thomas W. Kenny[1]
[1]Stanford University, USA and [2]Apple Inc., USA

In this work, we designed an oven controlled MEMS oscillator (OCMO) with ppb level performance over 100C temperature range and sub 10mW power consumption. The dual-mode, single-resonator design with in-plane micro oven allows precise measurement of the operating temperature, low power and control of the output frequency. This device exhibits record breaking performance with a MEMS resonator.

W3P.090 APERTURE-COUPLED MICROSTRIP RESONATOR FOR MILLIMETER-WAVE PASSIVE PRESSURE SENSORS

Maria V. De Paolis, Julien Philippe, Alexandre Rumeau, Anthony Coustou, Samuel Charlot, Hervé Aubert, and Patrick Pons
LAAS-CNRS, FRANCE

A mm-wave passive pressure sensor based on an aperture-coupled microstrip resonator is proposed. The aperture-coupling technique is applied here for improving the air-tightness of the pressure sensors and for avoiding unwanted EM radiation occurring when using the probe-fed technique. The measured additional insertion loss due to the aperture-coupling is found to be of 1.4dB only. Both EM simulation results and experimental data are reported for the validation of the novel mm-wave sensor design.

W3P.091 CHARACTERIZATION OF SILICON CARBIDE PRESSURE SENSORS AT 800 °C

Robert S. Okojie[1], Dorothy Lukco[2], Carl W. Chang[2], and Ender Savrun[3]
[1]NASA Glenn Research Center, USA, [2]Vantage Partners, LLC, USA, and [3]Sienna Technologies, Inc., USA

The characterization of SiC piezoresistive pressure sensors at 800 C is reported. Of significance is the increase in pressure sensitivity with increasing temperature beyond 400 C. At 800 C the sensitivity was equal to or higher than the room temperature value. The sensor can now be inserted further into the combustion chamber, thus capturing wider bandwidth of pressure frequencies over the semi-infinite tube method.

W3P.092 COMPARISON OF THERMO-RESISTIVE AND THERMO-ELECTRONIC TRANSDUCTION METHODS IN THERMAL FLOW SENSORS

Ethan L.W. Gardner[1], Timothy A. Vincent[2], Andrea De Luca[2], and Florin Udrea[1]
[1]University of Cambridge, UK and [2]Flusso Ltd, UK

This paper investigates the differences between thermo-resistive and thermo-electronic flow sensors across 3 SOI CMOS designs. The two transduction principles (hot wire and thermo-diode) are both embedded within the same sensor, allowing for the first time, a fair and complete comparison.

W3P.093 DUAL CHANNEL MICROFLUIDIC RESONATORS FOR SIMULTANEOUS MEASUREMENTS OF LIQUID ANALYTES

Jaeseob Lee[1], Faheem Khan[2], Thomas Thundat[3],[4], and Jungchul Lee[1]
[1]Korea Advanced Institute of Science and Technology (KAIST), KOREA,
[2]Fourien Inc., CANADA, [3]University of Alberta, CANADA and [4]University at Buffalo, USA

This paper reports microfluidic resonators with two independent channels integrated for simultaneous measurements of different or same liquid analytes, for the first time. Such a unique design intrinsically enables independent access of each integrated fluidic channel. In addition, an off-chip vacuum clamp with microfluidoc feed-throughs is custom made to operate the resonators at a high quality factor.

W3P.094 ELASTIC MODE SEMICIRCULAR BEAMS RESONATOR OSCILLATOR WITH WEAKENED NONLINEARITIES

Dongyang Chen[1,2], Jiangkun Sun[2,3], Miland Pandit[2], Guillermo Sobreviela[2], Xuying Chen[1], Ashwin Seshia[2] and Jin Xie[1]
[1]Zhejiang University, CHINA, [2]University of Cambridge, UK and
[3]National University of Defense Technology, CHINA

This paper reports on the development of a technique that suppresses Duffing nonlinearity in MEMS resonator. The proposed scheme of Duffing nonlinearity localization is implemented via confinement of nonlinear extension energy in beams resonator to lead to a mode transition from stretch to elastic vibration mode. Experimental results show that the weakened instability of amplitude-frequency effect is only 1.3% of that of conventional double-ended tuning forks resonator.

W3P.095 EXPERIMENTALLY OBSERVED NONLINEAR DISSIPATION LINKED TO CONTRIBUTIONS FROM GAS DAMPING AND TED IN MEMS FLEXURAL MODE RESONATORS

Anne L. Alter[1], Gabrielle D. Vukasin[1], Ian B. Flader[2], Hyo Jin Kim[1], Yunhan Chen[3], Daniel D. Shin[1], and Thomas W. Kenny[1]
[1]Stanford University, USA, [2]Invensense Inc., USA, and [3]Apple Inc., USA

We present an investigation into the origin of nonlinear dissipation in MEMS flexural mode resonators driven in a highly nonlinear regime. By comparing devices with different combinations of thermoelastic and gas damping, and utilizing the ringdown response at different pressures, we observe a larger presence of nonlinear dissipation in pressure damped resonators, but continue to observe some nonlinear dissipation at high vacuum suggesting additional contributions from thermoelastic dissipation.

W3P.096 GENETIC ALGORITHM FOR THE DESIGN OF FREEFORM GEOMETRIES IN A MEMS ACCELEROMETER COMPRISING A MECHANICAL MOTION PRE-AMPLIFIER

Chen Wang[1,5], Huafeng Liu[2], Xiaoxiao Song[2], Fang Chen[3], Ioannis Zeimpekis[4], Yuan Wang[5], Jian Bai[1], Kaiwei Wang[1], and Michael Kraft[5,6]
[1]Zhejiang University, CHINA, [2]Huazhong University of Science and Technology, CHINA,
[3]Chinese Academy of Sciences (CAS), CHINA, [4]University of Southampton, UK, [5]University of Liege, BELGIUM, and [6]University of Leuven, BELGIUM

We developed a novel, semi-automated design methodology based on a genetic algorithm using freeform geometries for micro-electro-mechanical systems (MEMS) devices. A MEMS accelerometer comprising a mechanical motion amplifier is presented to demonstrate the effectiveness of the design approach. Experimental results show a figure of merit (defined as the product of sensitivity and bandwidth) improvement by 100% and a sensitivity improvement by 141%.

W3P.097 GUIDELINES FOR MULTISENSOR SYSTEM CALIBRATION WITH AND WITHOUT REGULARIZATION

Moritz Berger, Felix Becker, and Oliver Paul
University of Freiburg, GERMANY

This paper develops guidelines for the efficient calibrating of linear multisensor systems (MSS). Calibration involves some form of regression analysis, e.g. with regularization, between nc calibration combinations of nl measurands applied to the system and the signals extracted from its ns sensors. The selection of a suitable nc is delicate, and the effectiveness of regularization critically depends on nl and nc vs. ns. This work addresses these trade-offs and formulates general conclusions.

W3P.098 HIGH SENSITIVE STRUCTURE OF NANOMECHANICAL GAS SENSOR BASED ON STRESS CONCENTRATION GENERATED BY CANTILEVER LATERAL DEFLECTION

Zhuqing Wang[1], Takumi Hokama[1], Masaya Toda[1], Mai Yamazaki[2], Krzysztof Moorthi[2], and Takahito Ono[1]
[1]Tohoku University, JAPAN and [2]Mitsui Chemical, Inc., JAPAN

We design and fabricate a high sensitive nanomechanical gas sensor, which is more sensitive than convemtional ones. To get high sensitivity, the receptor part is embedded into between hard frame and a cantilever. This gas sensor is developed by microfabrication process. Applying dip coating method, the sensor is coated on with polymer solution as a receptor part. The sensor shows good responsibility and repeatability for several humidity changes. Moreover it also reacts to acetone and ethanol.

W3P.099 HIGH-TEMPERATURE PIEZOELECTRIC PRESSURE SENSORS FOR HYPERSONIC FLOW MEAUSUREMENTS

Yoonho Seo[1], Donghwan Kim[2], and Neal A. Hall[1]
[1]University of Texas, Austin, USA and [2]Silicon Audio, Inc., USA

A microelectromechanical-system piezoelectric acoustic sensor for measurements in hypersonic flows at extreme temperatures (>1000 °C) is presented. Diaphragms employ aluminum nitride as the sensing material. The sensors capture hypersonic-flow-specific features in field measurements, including shock waves and second-mode instabilities associated with laminar-to-turbulent transition. High-temperature operation is demonstrated as the sensors capture audio while immersed in butane flame.

W3P.100 IMPROVED REFERENCE-FREE VIBRATION-SUPPRESSED OPTICAL MEMS ELECTRIC FIELD STRENGTH SENSOR

Andreas Kainz[1], Harald Steiner[2], Wilfried Hortschitz[2], Johannes Schalko[1], Artur Jachimowicz[1], and Franz Keplinger[1]
[1]Vienna University of Technology, AUSTRIA and [2]Danube University Krems, AUSTRIA

This contribution shows a distortion-free electric field strength sensor based on a completely passive micromechanical structure with significantly improved suspension for vibration suppression. With this suspension, the responsivity to electric fields was increased while the responsivity to vibrations was decreased by separating the according modes. This trend can be continued to achieve even more robust and more sensitive sensors.

W3P.101 INFLUENCE OF MOLECULAR DEGREES OF FREEDOM ON THE GAS DAMPING BEHAVIOR OF MICRO-OSCILLATORS IN THE MOLECULAR FLOW REGIME

Tobias Zengerle[1], Julian Joppich[1], Abdallah Ababneh[2], Patrick Schwarz[1], Karin Bauer[1], and Helmut Seidel[1]
[1]University of Saarland, GERMANY and [2]Yarmouk University, JORDAN

The activation process of polyatomic rotational and vibrational degrees of freedom (DOF) is observed with microsecond resolution by investigating the damping on micro-oscillators in the molecular flow regime. The effect of additional activated DOF is taken into account by adapting a thermodynamic excitation model and therefore expands the theory in the molecular damping regime.

W3P.102 MAGNETIC FIBER SENSING BY MAGNETO-IMPEDANCE EFFECT WITH TIME-DOMAIN-REFLECTOMETRY

Kazuma Takenaka
Yokogawa Electric Corp., JAPAN

We develop a magnetic fiber sensing system which detects the position and strength of a magnetic field simultaneously with simple and flexible components, enabling continuous magnetic profile monitoring along the entire length of a sensor cable, and requires less work and time than conventional single-point measurement by chip-type magnetic sensors.

W3P.103 METASURFACE BASED UNCOOLED MICROBOLOMETER WITH HIGH FILL FACTOR

Omar Alkorjia[1], Amjed Abdullah[1], Akshay Koppula[1], Cameron Warder[1], Tao Liu[2], Chuang Qu[2], Chen Zhu[3], Edward Kinzel[2], and Mahmoud Almasri[1]
[1]University of Missouri, USA, [2]Missouri University of Science and Technology, USA and [3]Notre Dame University, USA

we present the design, fabrication, characterization, and noise reduction of metasurface based uncooled infrared (IR) microbolometers. In this design, the devices were fabricated with the legs positioned underneath the microbolometer pixel without disrupting the _-wave resonance. This permits longer legs without sacrificing the fill factor in a focal plane array. The longer legs allow the thermal resistance between the microbolometer and the substrate.

W3P.104 MICRO STRUCTURED HOT FILM SENSOR ARRAYS FOR THE ANALYSIS OF COHERENT STRUCTURES IN TURBULENT AND TRANSITIONAL FLOWS

Karin Bauer[1], Rafael Knobling[2], Sven Scharnowski[2], Christian Kähler[2], and Stephen Rolston[3]
[1]Universität des Saarlandes, GERMANY, [2]Universität der Bundeswehr, GERMANY, and [3]Airbus Central R&T, UK

Novel arrays of micro-structured hot film sensors (μHFS) on thin polyimide foils enable the identification and tracking of coherent flow structures propagating in turbulent and transitional flows. The micro-manufactured μHFS arrays with their electronic system operate at very high temporal and good spatial resolution. They allow detailed analysis of time dependent flow behavior e.g. in flow reattachment at low speed and in transition at high-speed external flows.

W3P.105 MICROPROBE WITH 3D ORTHOGONAL KINEMATICS FOR DIMENSIONAL MEASUREMENT OF INDUSTRIAL MICROPARTS

David Metz[1], Stephan Jantzen[2], Martin Stein[2], Karin Kniel[2], and Andreas Dietzel[1]
[1]Technical University of Braunschweig, GERMANY and [2]Physikalisch-Technische Bundesanstalt, GERMANY

We have developed a silicon-based microprobe that enables micromeasurements on commercially available coordinate measuring machines. The microprobe consists of three identical cells that measure deflection in orthogonal directions. These microfabricated cells offer a large measuring range and low stiffness in only one direction, due to their silicon parallelogram structure. Assembled, the cells form an isotropic microprobe with piezoresistive sensing for measuring submicrometer deflections.

W3P.106 OBJECT RECONSTRUCTION IN MICROWAVE BASED NON-DESTRUCTIVE TESTING

Maxim Nesterov[1], Thomas Gagelmann[1], Cuihua Li[2], Sebastian Wöckel[1], Sebastian Hantscher[2], and Jörg Auge[2]
[1]Institute F. Automation und Kommunication (ifak), GERMANY and
[2]Magdeburg-Stendal University of Applied Sciences, GERMANY

We present a suitable method for non-destructive testing (NDT) with microwaves. This paper shows the results concerning the improvement of resolution of object reconstruction and defect classification with microwave based methods. The paper mainly describes the soft-sensing technology by enhanced antenna modelling and algorithm-based (autonomous) interpretation of the measured reflection signatures.

W3P.107 PDMS-ENCAPSULATED CRACK SENSOR INTEGRATED WITH SILICON RUBBER CANTILEVER FOR USE IN CELL CULTURE MEDIA

Dong-Su Kim[1], Yong Whan Choi[2], Mansoo Choi[3], Eung-Sam Kim[1], Bong-Kee Lee[1], and Dong-Weon Lee[1]
[1]Chonnam National University, KOREA, [2]Silla University, KOREA, and [3]Seoul National University, KOREA

We propose a novel cantilever structure integrated with a high-sensitive and -reliable crack sensor that can precisely measure the contraction behavior of cardiomyocytes in media. In addition, the proposed crack sensor is chemically bonded with a PDMS thin layer to form a sandwich structure which operates stably in an electrolyte solution such as culture media. The high-sensitive crack sensor stably measures the contractility of cardiomyocytes without changing a gauge factor for up to 26 days.

W3P.108 REAL-TIME PARTICLE SPECTROMETRY IN LIQUID ENVIRONMENT USING MICROFLUIDIC-NANOMECHANICAL RESONATORS

Alberto Martín-Pérez, Daniel Ramos, Javier Tamayo, and Montserrat Calleja
Institute of Micro and Nanotechnology (IMN-CNM-CSIC), SPAIN

In this work we develop a low-cost mass sensor based on a hollow nanomechanical resonator for particle detection in liquid environments. Using a nanomechanical resonator provided with an integrated microchannel allows real-time and high throughput particle mass sensing while taking advantage from microfluidic phenomena may appear inside the microchannel.

W3P.109 SEISMIC RECORDING USING A MODE LOCALIZED MEMS ACCELEROMETER

Milind Pandit[1], Chun Zhao[2], Guillermo Sobreviela[1], Xudong Zou[3], and Ashwin A. Seshia[1]
[1]University of Cambridge, UK, [2]Huazhong University of Science and Technology, CHINA, and
[3]Chinese Academy of Science, CHINA

This paper reports the first demonstration of a mode localized resonant accelerometer (MLRXL) as a seismometer. With a noise floor of 4.5µg/√Hz the sensor captured an earthquake of Richter magnitude 3.8 with the epicenter at Grimsby, UK on the 9th of June, 2018. This measurement demonstrates the potential for mode localized MEMS accelerometers to be utilized for seismic applications with comparable performance to existing seismometers, with particular relevance to long-period measurements.

W3P.110 SILICON CARBIDE PRESSURE SENSORS FOR HARSH ENVIRONMENTS

Arnold C. Hoogerwerf, Guido Spinola Durante, Rony Jose James, Marc-Alexandre Dubois, Olivier Dubochet, and Michel Despont
Centre Suisse d'Electronique et de Microtechnique (CSEM), SWITZERLAND

We have developed silicon carbide pressure sensors for operating temperatures of up to 600degC. The major technology blocks developed are: the metal-to-SiC contacts for high temperature operations, the etching of up to 300um deep trenches in SiC, and the hermetic bonding of SiC-to-SiC to create the reference cavity for the absolute pressure sensors.

W3P.111 SUPER SPATIAL RESOLUTION PRESSURE IMAGE SENSOR BASED ON A BONDING TECHNIQUE OF PVDF FILM ON TWO MICROMETER PITCH CMOS POTENTIOMETRIC SENSOR ARRAY

You-Na Lee[1], Kanata Tanaka[1], Kensuke Murakami[1], Ken Ogasahara[2], Satoshi Shimizu[2], Yasuyuki Kimura[1], Tomoko Horio[1], Takeshi Hizawa[1], Tatsuya Iwata[1], Kazuhiro Takahashi[1], and Kazuaki Sawada[1]
[1]Toyohashi University of Technology, KOREA and [2]Toho Kasei Co., LTD., JAPAN

We develop new pressure sensing chips consisting of 65,536 (256_256) array of piezoelectric ion-sensitive field-effect-transistors (PISFETs) which can not only measure pressure changes on the contacted surface simultaneously, but also visualized in 2D images in real-time. To fabricate the sensor, we also proposed a simple and high reproducible bonding technique.

W3P.112 SWITCHING THERMAL PIEZORESISTIVE OSCILLATORS FROM DAMPED TO SELF-SUSTAINED REGIME USING TUNABLE RESISTORS

Pierre Janioud[1,2], Alexandra Koumela[1,2], Christophe Poulain[1,2], Stephan Louwers[1,2], Carine Ladner[1,2], Panagiota Morfouli[2], and Guillaume Jourdan[1,2]
[1]CEA - LETI, FRANCE and [2]University Grenoble Alpes, FRANCE

Over the last few years, Thermal Piezoresistive Back Action (TPBA) in biased silicon nanobeams has demonstrated its interest to control the quality factor of resonant sensors. This paper reports a new technique to switch the sign of the TPBA viscous force during device operation using tunable resistors embedded in the biasing circuit. For a specific value of the resistor, damping rate becomes independent of the biasing voltage, thus cancelling TPBA effect in the device.

W3P.113 TEMPERATURE SENSOR USING TWO THERMOELECTRIC LIQUID ELECTROLYTE IN MICROFLUIDIC CHANNELS

Naoki Inomata, Nguyen Van Toan, and Takahito Ono
Tohoku University, JAPAN

A temperature sensor using two thermoelectric liquid electrolyte in microfluidic channels is proposed, and fabricated, and evaluated. Two different electrolytes, one is positive thermo-voltage, another is negative, are electrically connected via metal electrodes; then, the total thermo-voltage from two electrolytes is observed changing the temperature of the contact area. The proto-type is fabricated, and the performance of thermo-voltage response is evaluated.

W3P.114 THERMAL PIEZORESISTIVE Q TUNING OF P-TYPE SILICON RESONATOR WITH FEEDTHROUGH REDUCTION

Sen Xu and Man Wong
Hong Kong University of Science and Technology, HONG KONG

Presently reported is the voltage-induced tuning of the quality factor (Q) of the resonator under a constant voltage source with a feedthrough reduction configuration by appliing a silicon-migration technology. As a result, the signal to noise lever is improved from 1.5dB to 15dB, and Q is improved from 208 to 448.

W3P.115 VERTICALLY INTEGRATED MULTIPLE ELECTRODE DESIGN FOR SENSITIVITY ENHANCEMENT OF CMOS-MEMS CAPACITIVE TACTILE SENSOR

Meng-Lin Hsieh, Sheng-Kai Yeh, Jia-Horng Lee, Pen-Sheng Lin, Mei-Feng Lai, and Weileun Fang
National Tsing Hua University, TAIWAN

This study presents novel capacitive tactile sensors with vertically integrated double deformable electrodes array based on the standard CMOS platform. The merits: vertically integrating double deformable structures by using multi-stacked thin films of CMOS process; electrically connecting the deformable and fixed electrodes to enhance initial capacitance and capacitance change under the same footprint; discretizing sensor into a 5 by 5 sensing unit array to reduce residual stress warpage.

W3P.116 WHY IS THERE MODE ORDERING IN DISK RESONATOR GYROS?

Eli Benvenisty, Sahar Lustig, and David Elata
Technion - Israel Institute of Technology, ISRAEL

We provide a rational explanation for mode ordering observed in disk resonating gyros. In disk gyros that are made from (100) silicon, it has been shown that in contrast to the 2nd order (elliptic) wineglass mode, the 3rd order (triangular) wineglass mode is insensitive to material anisotropy. However, surprisingly, the natural frequency of the 3rd order wineglass mode may be lower than that of the 2nd order mode. Our analysis provides new insight and rationally explains this phenomenon.

Monday - Medical Microsystems

M3P.117 A CONTINUOUS AND WEARABLE BLOOD PRESSURE MEASUREMENT DEVICE WITH MEMS 3-AXIS FORCE SENSOR ARRAY

Tetsuji Dohi[1], Hisashi Urata[1], Shun Fukahori[1], Masataka Hori[1], Akihito Nakai[2], and Hiroyuki Nakamura[3]
[1]Chuo University, JAPAN, [2]University of Tokyo, JAPAN, and [3]Shinano Kenshi Co., Ltd., JAPAN

Our group is developing wearable devices that can continuously measure blood pressure by applying MEMS 3-axis force sensor array to the tonometry method. We fabricated the prototype devices for verifying the principle and the product like device with limited function, but small and good appearance. Since we realized reduction of body motion noise by comparing the outputs of sensor array, we can continuously measure the blood pressure even if the subject moves somewhat during daily life.

M3P.118 ADVANCES IN MANUFACTURING OF BIODEGRADABLE SPINAL CORD IMPLANTS ON MICROSCALE THROUGH MICROMOLDING AND 3D PRINTING

Jana M. von Poblotzki, Timo Lipka, Christian Voss, and Hoc K. Trieu
Technical University of Hamburg, GERMANY

We developed a mechanical microconnector system (mMS) to help regenerate after spinal cord injury (SCI). The implantable mMS is transferred from biocompatible to biodegradable material via micromolding using a 3D printed quartz glass premaster. For individual treatment of SCI and automatic production out of MRT data, the involvement of a 3D printing method is an important advance. The technique is optimized for three polymers which are widely used for biodegradable implants.

M3P.119 CUBIC FLOCKED ELECTRODE EMBEDDING AMPLIFIER CIRCUIT FOR SMART ECG TEXTILE APPLICATION

Toshihiro Takeshita, Manabu Yoshida, Yusuke Takei, Atushi Ouchi, and Takeshi Kobayashi
National Institute of Advanced Industrial Science and Technology (AIST), JAPAN

We proposed novel dry electrode structure which was PDMS cube on which Ag-plated fiber was flocked by electrostatic flocking technology. Also, ECG amplifier circuit was embedded inside the PDMS cube. The structure realized stable contact pressure. Also, reduction of wiring noise was expected because the ECG signal can be amplified near the electrode. Because electrical devices such as MEMS, MCU and RF-IC can be also embedded inside the cubic dry electrode using this electrode structure

M3P.120 IN SITU SENSOR ELECTRODE PATTERNING ON URINARY CATHETERS TOWARDS INFECTION PREVENTION

Ryan C. Huiszoon, Sangwook Chu, Luke A. Beardslee, Pradeep Ramiah Rajasekaran, William E. Bentley, and Reza Ghodssi
University of Maryland, USA

This paper presents a novel in situ fabrication strategy for patterning electrodes directly on a urinary catheter surface via an innovative electroplating process. Our approach enables bacterial biofilm monitoring via real-time impedance measurement without interfering with the operation of the catheter and overcoming manufacturing challenges associated with fabricating devices on flexible substrates and subsequently conforming them to complex, curved surfaces vulnerable to biofilm.

M3P.121 OPTICAL BLOOD CLOTTING SENSOR FOR AN ARTIFICIAL CIRCULATION APPARATUS

Nobutomo Morita, Daisuke Sakota, Kazuki Kondo, Toshihiro Takeshita, Ryo Kosaka, Akiko Oota-Ishigaki, Masahiro Nishida, Osamu Maruyama, and Wataru Iwasaki
National Institute of Advanced Industrial Science and Technology (AIST), JAPAN

We developed micro optical sensor for detecting blood clotting in an artificial circulation apparatus such as blood pump. We have evaluated the blood clotting detection performance with porcine blood, then achieved to detect blood clotting. The sensor consists of three LEDs, CMOS chip which have monolithically-fabricated photodiodes (PD) and amplifier circuits. The small sensor size 2.8×2.8×0.5 mm^3 enable to be mounted and measure various points of artificial circulation apparatus.

M3P.122 REAL-TIME TRACKING OF A 3D-PRINTED SMART CAPSULE USING ON-BOARD NEAR-INFRARED LED ARRAY

Hongjie Jiang[1], Albert Kim[2], Jiawei Zhou[1], Rahim Rahimi[1], and Babak Ziaie[1]
[1]Purdue University, USA and [2]Temple University, USA

This work utilizes the near infrared penetration of light within the tissue for real-time tracking of a 3D-printed capsule. Ex-vivo experiments using porcine tissue, three 875 nm NIR-LEDs and a paired photodiode receiver showed a light penetration depth of 6.2cm. Three batteries (1.5V, 10mAh) can provide enough power to continuously track the capsule in the small intestine for 2 hours, thus providing a good coverage of capsule positioning in the jejunum.

Tuesday - Medical Microsystems

T3P.116 A HIGH-DENSITY ARRAY OF 3D MICRONEEDLE-ELECTRODES FOR EVALUATION OF SPATIAL RESOLUTION OF NEURONAL ACTIVITY

Yuta Kotani[1], Hirohito Sawahata[2], Shota Yamagiwa[1], Rika Numano[1], Kowa Koida[1], and Takeshi Kawano[1]
[1]Toyohashi University of Technology, JAPAN and
[2]National Institute of Advanced Industrial Science and Technology, JAPAN

To understand how the brain works, it is necessary to explore the behavior of the micro-scale neural network with a high spatial resolution. Here, we propose silicon growth-based needle-electrode arrays with the minimum electrode's interval of 150 μm. To evaluate the spatial resolution of neuronal signal, a 1 _ 8 array of needle-electrodes penetrated into barrel cortex of a mouse, and the recorded spike signals were analyzed using the spike firing-rates.

T3P.117 AUTOMATED HIGH-CONTENT PHENOTYPING OF THE NEMATODE *C. ELEGANS* AT SINGLE ANIMAL RESOLUTION WITH A MICROFLUIDIC PLATFORM

Huseyin B. Atakan, Rongrong Xiang, Matteo Cornaglia, Laurent Mouchiroud, Johan Auwerx, and Martin Gijs
École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND

In this work, we present a novel microfluidic approach to culture the nematode C. elegans from the onset of embryogenesis to the adult stage at single animal resolution. Our device allows high-throughput experimentation, high-resolution imaging, thereby providing high-content phenotyping in a highly parallel fashion. Our validation study with an anthelmintic drug, tetramisole, revealed a clear impact of tetramisole on various worm phenotypes.

T3P.118 DOUBLE-BALLOONED LOCAL DRUG DELIVERY CATHETER WITH BLOOD BYPASSING FUNCTION

Zi-Yu Huang[1], Yuan Luo[1], Parinaz Abiri[2], Rene R.S. Packard[2], Tzung K. Hsiai[2], and Yu-Chong Tai[1]
[1]California Institute of Technology, USA and [2]University of California, Los Angeles, USA

For the first time, a double-ballooned catheter that enables both local drug delivery and blood bypassing at the same time is demonstrated. Such catheters are targeted for potentially long period of high-dose local drug treatment of cardiovascular diseases, such as atherosclerosis and restenosis, but without causing downstream ischemia. The functionalities of the catheter are validated in both benchtop and live pig experiments (i.e., using angiogram) with videos.

T3P.119 MAGNETICALLY CONTROLLED MICROROBOT FOR EMBRYO TRANSFER IN ASSISTED REPRODUCTIVE TECHNOLOGY

Susumu Koseki[1], Kazuhiro Kawamura[2], Futoshi Inoue[3], Koji Ikuta[1], and Masashi Ikeuchi[1]
[1]University of Tokyo, JAPAN, [2]International University of Health and Welfare, JAPAN, and
[3]Kitazato Corporation, JAPAN

We propose a new magnetically controlled microrobot system for embryo transfer in Assisted Reproductive Technology (ART). The first prototype of the system composed of a microrobot and a catheter was demonstrated with a human phantom. In this system, the microrobot accommodates and transports an embryo into the patient's uterus and controls the position of implantation magnetically. The catheter can catch and release the microrobot with a sensing system for the state of catch/release.

T3P.120 MEMS SILICON CUTTERS FOR RAPID SECTIONING OF DIFFUSION-LIMITED PANCREATIC ISLETS TO IMPROVE VIABILITY

Colin Cook[1], Hirotake Komatsu[2], Mayra Salgado[2], Yoko Mullen[2], Fouad Kandeel[2], and Yu-Chong Tai[1]
[1]California Institute of Technology, USA and [2]Beckman Research Institute of City of Hope, USA

MEMS silicon cutters are designed to rapidly section donor pancreatic islets below oxygen diffusion-limited dimensions to improve viability of grafts during re-implantation and revascularization. The monolithic silicon chips feature an array of spaced nano-sharp blades that cleanly section islet tissue under the applied force of a syringe. We demonstrate that sectioning of pancreatic islets is a feasible strategy to overcome hypoxia and core-necrosis.

T3P.121 OPTICAL MEASUREMENT OF PRINCIPAL STRESS ON RETINAL MODEL USING DIGITAL IMAGE CORRELATION FOR VITREORETINAL SURGERY SIMULATOR

Hisataka Maruyama, Masaki Tsubaki, Kazuma Okuda, Seiji Omata, Taisuke Masuda, and Fumihito Arai
Nagoya University, JAPAN

We developed the non-contact measurement of principal stress distribution on a retinal model for vitreoretinal surgery simulator. The retinal model reproduces Young's modulus of human retina and sclera, respectively. Digital image correlation (DIC) was used to measure the deformation on the retinal model at subpixel resolution. We demonstrated the measurement of the distribution of maximum principal stress on the retinal model surface during the pushing by the forceps.

T3P.122 TOWARD A QUANTITATIVE EVALUATION OF THE FALL RISK USING THE FUSION OF INERTIAL SIGNALS AND ELECTROMYOGRAPHY WITH WEARABLE SENSORS

Ivan Mazzetta[1], Alessandro Zampogna[1], Antonio Suppa[1,2], Marco Pessione[3], and Fernanda Irrera[1]
[1]Sapienza University of Rome, ITALY, [2]IRCSS NEUROMED Institute, ITALY and [3]STMicroelectronics, ITALY

Fusion of inertial and electromyographic signals allows distinguishing the trembling freezing of gait (FOG) of Parkinson's Disease (PD) patients. This can help doctors evaluating the patient's fall risk. Our wearable system monitors in free-living condition the activity type and intensity of the antagonist muscles involved in FOG. This is an advancement of the state-of-art knowledge of the PD pathophysiology and can allow therapeutic strategies as dedicated proprioceptive muscle manipulation.

Wednesday - Medical Microsystems

W3P.117 A WIRELESS PARYLENE-BASED CARDIOVASCULAR PRESSURE SENSOR WITH MXENE FILM

Shao-Hsiang Lo, Ming-Xin Xu, and Yao-Joe Yang
National Taiwan University, TAIWAN

This work presents a wireless flexible passive pressure sensor for monitoring blood pressure. The sensor can be inserted into a stent for catheter-based delivery into the body. The device consists of an inductor and a capacitor with a multilayer MXene powder film. The inductor and the capacitor form a resonant tank that enable wirelessly retrieving signals by using the phase-dip technique. Experimental results showed that the MXene film enhances the device linearity and dynamic range.

W3P.118 AUTOMATED HIGH-THROUGHPUT HERMETIC FAILURE MONITORING SYSTEM FOR MILLIMETER-SIZED WIRELESS IMPLANTABLE MEDICAL DEVICES

Pyungwoo Yeon, Min-gu Kim, Muhannad S. Bakir, Oliver Brand, and Maysam Ghovanloo
Georgia Institute of Technology, USA

To protect sophisticated electronics from harsh body environment as well as the body from potential toxic chemicals in the package of the implantable biomedical devices (IMDs), a lifetime estimation for the hermetic package of the IMDs is a key part of IMD development. Our developed automated high-through-put hermetic failure monitoring system can enable lifetime estimations for multiple mm-sized wireless IMDs at low cost and in a user-friendly setup.

W3P.119 AUTOMATIC MEMBRANE-BASED MICROFLUIDIC PLATFORM FOR INVESTIGATING THE EMERGENCE OF PATHOGENICITY

Can Huang[1], Han Wang[2], Paul De Figueireido[1], and Arum Han[1]
[1]Texas A&M Univeristy, USA and [2]Tsinghua University, CHINA

A membrane-based automated microfluidic platform was proposed and optimized to conduct repetitive infection assay in order to investigate the emergence of pathogenicity. Naive E. Coli strain mixed with macrophages was introduced into the platform to repetitively select sub-population with enhanced survival capability. Harvested E. Coli strain was characterized and the feasibility of the platform was confirmed.

W3P.120 IMPLANTABLE 3D PRINTED DRUG DELIVERY SYSTEM

Khalil Moussi, Abdullah Bukhamsin, and Jurgen Kosel
King Abdullah University of Science and Technology (KAUST), SAUDI ARABIA

A miniaturized drug delivery system suitable for in-vivo biomedical applications is presented. A two-photon polymerization 3D printing technique was used to fabricate a reservoir equipped with microneedles. The assembled system achieved delivery of 4 ± 0.5 µL within 12 seconds of actuation. A penetration test of the microneedle into a skin-like material confirms its potential for transdermal delivery.

W3P.121 MICRO-MACHINEED CATHETER SENSOR SYSTEMATIZATION FOR IN-SITU BREATHING AND OPTICAL IMAGING MEASUREMENTS IN BRONCHUS REGION IN LUNG SYSTEM

Yoshifumi Maeda[1], Chiaki Okihara[1], Yoshihiro Hasegawa[1], Kazuhiro Taniguchi[1], Miyoko Matsushima[2], Tsutomu Kawabe[2], and Mitsuhiro Shikida[1]
[1]Hiroshima City University, JAPAN and [2]Nagoya University, JAPAN

Novel type of systemized catheter sensor was proposed for realizing in-situ both breathing and optical imaging measurements in bronchus region in lung system. Assembled tube flow sensor on to a medical basket forceps and an optical fiberscope were systemized with size less than 5.0 mm in diameter. The developed catheter sensor system was inserted into a rabbit airway by using fiberscope, and we confirmed that it can directly measure both breathing airflow and inside surface image simultaneously.

W3P.122 REAL-TIME COMPACT IDENTIFICATION SYSTEM OF AMPLIFIED TARGET RNA BASED ON A FILTER-FREE MULTIPLE WAVELENGTHS SENSOR

Yong Joon Choi, Kazuhiro Takahashi, Toshihiko Noda, Tatsuya Iwata, Hiromu Ishii, and Kazuaki Sawada
Toyohashi University of Technology, JAPAN

We proposed an identification system of amplified target RNAs using a filter-free multiple wavelengths sensor. To detect fluorescence from transcription reverse transcription concerted reaction combined with intercalation activating fluorescence probe, a compact system fabricated with optimized physical parameters of light source and sensor. The fluorescence was successfully separated using the proposed parameters based on controlled the intensity of the excitation light and the potential depth.

W3P.123 WEARABLE IONTOPHORESIS DEVICE USING STRETCHABLE ELECTRODES TOWARDS TRANSDERMAL DELIVERY

Umihiro Kamoto, Yutaka Isoda, and Hiroki Ota
Yokohama National University, JAPAN

A wearable iontophoresis device using stretchable electrodes towards transdermal delivery of anticancer vaccination was developed in this study. Electronic current on skin during iontophoresis delivers charged drugs though the skin without a needle. The device is composed of stretchable electrodes and flexible polyimide substrate to improve the contact between the device and body. These technologies will realize the stable transdermal administration of drug for patients and doctors.

Monday - Microfluidics (Non-Bio)

M3P.123 3D-PRINTED CHAOTIC MIXER FOR LOW REYNOLDS NUMBER MICROFLUIDICS

Eric C. Sweet, Rudra R. Mehta, Yifan Xu, Nathaniel Liu, Casey Glick, and Liwei Lin
University of California, Berkeley, USA

This work presents 3D laminarflow chaotic fluidic mixing via novel intra-channel microscale 3D structures fabricated with an entirely-3D printed modular microfluidic mixing device. Our 3D μ-mixers can be integrated with other 3D microfluidic device designs along the μ-channel where efficient mixing is desired.

M3P.124 AN IDEP BASED SINGLE CELL ENCAPSULATION MICROFLUIDIC DEVICE USING LIFT-OFF TECHNIQUE

Gaurav P. Pendharkar[1], Meng-Ping Lu[2], Chia-Ming Chang[2], Chieh-An Jean[1], Yu-Chen Chen[1], Yen-Ta Lu[2], and Cheng-Hsien Liu[1]
[1]National Tsing Hua University, TAIWAN and [2]Mackay Medical College, TAIWAN

We present here an insulator based dielectrophoresis (iDEP) chip capable of single cell trapping and encapsulation with high efficiency. The proposed microfluidic chip can be easily tuned for trapping various size of cells. This microfluidic device is fabricated using a technique called lift off polydimethyl siloxane (PDMS). The fabrication technique eliminates the difficulty in handling a thin membrane with a large number of holes.

M3P.125 COST-EFECTIVE LAB-ON-A-CHIP DEVICE FOR SEAWATER PH QUANTIFICATION BY OPTICAL METHODS

Vania C. Pinto, Paulo J. Sousa, Victor H. Magalhães, Catarina F. Araujo, Graça Minas, and Luis M. Goncalves
University of Minho, PORTUGAL

A novel lab-on-a-chip device for seawater pH quantification based on the colorimetric methods, using the meta-Cresol Purple (mCP) as indicator dye was developed. The device integrates low-cost optical-electronics, microfluidic and micropumping systems, providing an autonomous, compact and portable platform for real-time, in-situ, long-term and low-cost seawater measurements. A response with high reproducibility and stability was obtained in a range from 7.50-8.40 pH units

M3P.126 DROPLET MANIPULATION USING AC EWOD-ACTUATED ANISOTROPIC RATCHET CONVEYORS

Di Sun, Gerardo Gomez, and Karl F. Böhringer
University of Washington, USA

This paper demonstrates an AC electrowetting-on-dielectric (EWOD) based platform to manipulate water droplets using anisotropic patterning with electrodes, without the need of complex controlling circuits. Only two electrodes are required to transport the droplet. By introducing DC EWOD electrodes, we can perform multiple droplet manipulating functionalities including droplet synchronizing, merging, and mixing.

M3P.127 ENHANCED RATIOMETRIC DETECTION USING A BURIED DUAL JUNCTION DIODE FOR A WEARABLE OPTOFLUIDIC BIOSENSING APPLICATIONS

Hyunjin Kim, Bing Wang, Dan Cohen, Bridget N. Queenan and Sumita Pennathur
University of California, Santa Barbara, USA

We demonstrate a novel integrated siliconburied dual-junction (BDJ) photodiode-basedsystem as the first step towards true microscaleintegration of an optofluidic wearable biosensor. To increase the sensitivity and signal to background ratio of our system, an effective filtering system was implemented which resulted in 1μM sensitivity in a ~7 μL of volume for fluorescence-based sensing.

M3P.128 HIGH-EFFICIENCY DIBROMINATION OF ORGANIC COMPOUND IN MICROFLUIDIC CHANNEL OF SI PILLAR ARRAY DIRECTLY COATED WITH IRON CATALYST

Takuo Sugaya[1], Daiki Tanaka[1], Dong Hyun Yoon[1], Yoshito Nozaki[1], Tetsushi Sekiguchi[1], Takashiro Akitsu[2], and Shuichi Shoji[1]
[1]Waseda University, JAPAN and [2]Tokyo University of Science, JAPAN

For highly efficient catalytic reaction, microfluidic device using directly iron catalyst coated Si micro pillar array was developed. 4,8-dibromo-1-hydroxy-2-naphthaldehyde was successfully synthesized in the microchannel. It was the first time that the organic compound was dibrominated in a microfluidic device. The proposed method achieved the reduction of reaction time without temperature control. This device can be applied for challenging synthesis which needs efficient catalytic reaction.

M3P.129 LIPID BILAYER BASED OPTOFLUIDIC LENS

Martin Oellers, Sander van den Driesche, and Michael J. Vellekoop
University of Bremen, GERMANY

We present the first optofluidic lens element based on a 4 nm thick lipid bilayer within a micromachined chip that is actuated by pressure. The lipid bilayer separates two liquids with different refraction index. The chip is mounted in a 3D printed casing that allows for in-situ optical monitoring of lens formation by pressurizing one of the two chambers.

M3P.130 RARE CIRCULATING TUMOR CELLS ISOLATION VIA SPIRAL-DEFORMED MICROFLUIDIC CHIP

Yixing Gou[1], Dahai Ren[2], Zheng You[2], Changku Sun[1], and Peng Wang[1]
[1]Tianjin University, CHINA and [2]Tsinghua University, CHINA

This paper presents a novel spiral-deformed inertial microfluidic system to capture circulating tumor cells (CTCs). In this chip, a 5-loop spiral channel and multiple expansion structures were designed to improve the separation performance of the spiral microfluidics based on theoretical modeling and simulations. Experiment results showed that the CTCs' recovery rate is over 90% and the purity can reach about 35%, much higher than conventional spiral microfluidics.

M3P.131 ZERO-LOSS OPTICAL SWITCH BASED ON IONIC LIQUID MICRODROPLET EWOD ACTUATION

Federico Ribet, Eleonora De Luca, Floria Ottonello Briano, Marcin Swillo, Niclas Roxhed, and Göran Stemme
KTH Royal Institute of Technology, SWEDEN

We realized and developed an optical shutter based on electrowetting-on-dielectric (EWOD) actuation of ionic liquid microdroplets. Due to the negligible evaporation of ionic liquids, the device can robustly operate in "open-air" and, thus, it provides zero insertion loss in the open state. Moreover, the device is compact and features low actuation voltage, zero static power consumption and broadband operation.

Tuesday - Microfluidics (Non-Bio)

T3P.123 A HIGH SENSITIVITY MICROFLUIDIC CHANNEL ENABLED TERAHERTZ METAMATERIAL ABSORBER FOR SENSING AND DETECTION

Guangwu Duan[1], Jacob Schalch[2], Xiaoguang Zhao[1], Aobo Li[1], Richard Averitt[2], and Xin Zhang[1]
[1]Boston University, USA and [2]University of California, San Diego, USA

In this paper, we utilized thin silicon nitride membrane as a supporting structure to eliminate the effect of the high permittivity of the bulk substrate to achieve metamaterial absorbers with a much higher high sensitivity and the fabricated devices demonstrate more than ^{3} times improvement in sensitivity.

T3P.124 AUTOMATIC PRETREATMENT FOR IN-SITU CRYOPRESERVATION OF SINGLE STEM CELLS BASED ON MICROFLUIDIC DROPLET MANIPULATION

Boshi Jiang, Bin Huang, Yan Chen, Xiaoyang Yu and Tianzhun Wu
Chinese Academy of Sciences (CAS), CHINA

We develop a cryopreservation pretreatment method using microfluidic chip featured with super-hydrophobic surfaces, including mechatronics design. The equipment automatically performed the smooth liquid exchange process and successfully completes the in-situ embryo cryopreservation pretreatment.

T3P.125 DEVELOPMENT OF A THERMORESPONSIVE VALVE MEMBRANE FOR MICROFLUIIC PAPER-BASED ANALYTICAL DEVICE

Wataru Iwasaki[1], Nobutomo Morita[1], Chiaki Sakurai[2], Yuta Nakashima[2], Yoshitaka Nakanishi[2], and Masaya Miyazaki[3,4]
[1]National Institute of Advanced Industrial Science and Technology (AIST), JAPAN,
[2]Kumamoto University, JAPAN, [3]Hokkaido University, JAPAN and [4]Kyushu Institute of Technology, JAPAN

We developed a thermoresponsive valve membrane by polymerizing thermoresponsive polymer, which becomes hydrophilic below, and hydrophobic above, the lower critical solution temperature (LCST; 32°C), in a porous membrane for fluid control in microfluidic paper-based analytical devices (μPADs). The valve membrane was able to prevent the passage of alkaline phosphatase at 25°C (< LCST) and path through the valve membrane and 40°C (> LCST).

T3P.126 EFFECTIVE ACOUSTIC FIELD GENERATION IN DISPOSABLE DISPENSING CARTRIDGES FOR ACOUSTOPHORETIC PARTICLE FOCUSING

Clara Siber[1,2], Lena A. Lautscham[1], Jonas Schoendube[1], Peter Reichert[3], Fabian Stumpf[1], Stefan Zimmermann[2], Roland Zengerle[2,4], and Peter Koltay[2,4]
[1]cytena GmbH, GERMANY, [2]University of Freiburg, GERMANY, [3]Swiss Federal Institute of Technology (ETH Zurich), SWITZERLAND, and [4]Hahn-Schickard, GERMANY

An optimized system for the application of acoustophoretic particle focusing to single-cell dispensing was developed and characterized. Effective acoustic field generation inside a microfluidic chip of a disposable dispensing cartridge by a detachable actuator was successfully shown. This ensures the reusability of the piezoelectric transducer. By admittance measurements it was demonstrated that the resonance spectrum of the piezoelectric actuator is largely independent of the cartridge.

T3P.127 FABRICATION OF PDMS MEMBRANE NANO FILTER USING SILICON MICROBLADE MOLD

Young-Ho Nam[1], Seung-Ki Lee[1], Jong-Ho Kim[2], and Jae-Hyoung Park[1]
[1]Dankook University, KOREA and [2]Hanyang University, KOREA

This paper presents a microfluidic device integrated with a PDMS membrane nano filter for the size-based trapping of particles. We proposed a novel cost-effective fabrication process to form submicron-sized nano-slit array in the PDMS membrane using reusable 3D silicon mold with the shape of microblade. Moreover, it was confirmed that the parylene-C thin film deposition process on the PDMS membrane filter can be effectively used to control the nano-slit size and improve the trapping efficiency.

T3P.128 *IN-SITU* VISUALIZATION OF WATER DROP CONDENSATION AT DIFFERENT TEMPERATURES USING THE COMBINATION OF A MICROFLUIDIC LIQUID CELL AND A SCANNING ELECTRON MICROSCOPE

Tadashi Ishida
Tokyo Institute of Technology, JAPAN

We developed the microfluidic liquid cell which had an 80-nm-thick electron transparent membrane and a microchannel, and in-situ observed the micro-scaled water drop condensations on the membrane under the atmospheric condition at different temperatures. The droplets condensed by the growth and coalescence. The growth rate of water drops increased due to the increase of coalescences, as the temperature around the microfluidic liquid cell increased.

T3P.129 MEMS DEVICE WITH PIEZOELECTRIC ACTUATORS FOR DRIVING MECHANICAL VORTEXES IN AQUEOUS SOLUTION DROPS

Marco Demori[1], Marco Baù[1], Marco Ferrari[1], Skandar Basrour[2], Libor Rufer[2], and Vittorio Ferrari[1]
[1]University of Brescia, ITALY and [2]Université Grenoble, Alpes, CNRS, FRANCE

This work presents a MEMS device with Aluminium Nitride (AlN) piezoelectric actuators on a silicon suspended plate developed for driving mechanical vortexes in aqueous solution. Innovatively, the MEMS device has the capability to force ClockWise (CW) or CounterClockWise (CCW) rotations of a fluid drop placed on the MEMS suspended plate. Experimental results show that CW and CCW rotations have been obtained using a 2 mm-diameter drop of water.

T3P.130 SCREEN PRINTED THERMAL FLOW VELOCITY SENSOR FOR MICROFLUIDIC DEVICES FEATURING INTRINSIC COMPENSATION OF SPURIOUS HEAT TRANSFER

Christina Offenzeller, Marcel Knoll, Bernhard Jakoby, and Wolfgang Hilber
Johannes Kepler University Linz, AUSTRIA

We present a fully screen printed sensor for measuring flow velocity inside microfluidic chips based on a modified anemometer principle. In contrast to previously reported sensor concepts, this device is designed to compensate for the spurious heat propagation in the substrate and heat conduction in the liquid. Using this approach it is possible to measure the flow velocity of any liquid in a channel directly by means of a single voltage without the need to correct for thermal side effects.

Wednesday - Microfluidics (Non-Bio)

W3P.124 A MEMS-BASED MICROSTRUCTURE SURFACE PROVIDING SUSPENSION PLATFORMS TO BUBBLES FOR EFFICIENT BOILING HEAT TRANSFER

Xinyue Chang, Yunna Sun, Yan Wang, and Guifu Ding
Shanghai Jiao Tong University, CHINA

An improved microstructure surface for efficient chip cooling by enhancing bubble dynamics was designed, fabricated and tested. The microstructure was numerically proved to form suspension platforms for bubbles' coalescing and departure. Experimental results indicate a significant increase in heat transfer property, delaying the formation of gas blanket. The microstructure made by low-cost route compatible with regular IC manufacture provides potential for industrial chip cooling applications.

W3P.125 CHITOSAN COATED IRON-OXIDE NANOPARTICLE SYNTHESIS USING A DROPLET BASED MICROFLUIDIC REACTOR

Malik Abdul Wahab and E. Yegan Erdem
Bilkent University, TURKEY and

We designed a droplet based microfluidic system for the synthesis of chitosan coated iron-oxide nanoparticles which have applications in drug delivery.

W3P.126 DROPLET DILUTION UNIT OPERATION INCLUDING BEAD WASHING USING INTEGRATED ACOUSTOPHORESIS

Zhenhua Liu, Anna Fornell, and Maria Tenje
Uppsala University, SWEDEN

We develop a microfluidic platform for on-chip droplet washing where the bead recovery also can be controlled. Background signal in the droplets is significantly reduced with maintained bead recovery by this on-chip washing method. The technology is applicable to all types of samples and does not require any labelling of the bioparticles.

W3P.127 ELECTRO-HYDRODYNAMIC DROPLET GENERATION, MANIPULATION, AND REPULSION OF OXIDIZED GALLIUM-BASED LIQUID METAL

Jinwon Jeong[1], Sang Kug Chung[1], Jeong-Bong Lee[2], and Daeyoung Kim[3]
[1]Myongji University, KOREA, [2]University of Texas, Dallas, USA, and
[3]Korea Army Academy at Yeong-Cheon, KOREA

We report on-demand size controllable droplet generation, falling direction manipulation, and repulsion of an oxidized gallium-based liquid metal by applying a strong electric filed. The size of gallium-based liquid metal droplets can be controllable by changing electric field. The direction of the falling droplet was tuned by changing the relative position between the needle and electrode. Finally, the electro-hydrodynamic liquid metal droplet repulsion was observed.

W3P.128 GOLD (WORKING), PLATINUM (COUNTER) AND SILVER (REFERENCE) NOVEL LEGO®-CONCEPTED MICROFLUIDIC CHIP FOR CAPILLARY ELECTROPHORESIS SEPARATION, ELECTROCHEMICAL AND MASS SPECTROMETRY DETECTIONS

Po-Hui Liu and Che-Hsin Lin
National Sun Yat-sen University, TAIWAN

This work presents a novel LEGO®-concepted microfluidic chip for capillary electrophoresis, electrochemical and mass spectrometry detections. A 3D-printed substrate equipped various detachable electrodes for applying the electric fields and electrochemical detection for CE-EC-MS. Therefore, the electrodes for the detection can be set on-demand for various kind of applications. In combining the thread-based microfluidic system, the time and experimental setup for producing a CE-EC chip.

W3P.129 INSPIRED BY NATURE: EFFICIENT PIEZOELECTRIC MEMS ACTUATOR BASED ON WAVELIKE EXCITATION

Regine Behlert and Gabriele Schrag
Technische Universität München, GERMANY

We conceived a novel integrated, piezoelectric MEMS actuator realized in an AlN thin-film technology and designed for mimicking fish locomotion for efficient fluid transport. A theoretical framework based on numerical simulations, wavelet transforms, and energy balance calculations allows for classifying the generated fluid flow field (determined experimentally or numerically). This way the flapper's efficiency can be assessed allowing for comparisons of various designs and excitation waveforms.

W3P.130 MICRO GAS CHROMATOGRAPHIC COLUMN EMBEDDED ELLIPTIC CYLINDRICAL PILLARS WITH LOW INLET PRESSURE AND SHORT SEPARATION TIME

Xuelwi Yang, Fei Feng, Bin Zhao, Bowen Tian, Haimei Zhou, and Xinxin Li
Chinese Academy of Sciences (CAS), CHINA

In this paper, a serpentine micro gas chromatographic (μGC) semi-packed column embedded elliptic cylindrical pillars (ECPs-column) with mesoporous silica as stationary phase was fabricated. Compared with μGC column with cylindrical pillars (CPs-column), effective width of ECPs-column was increased by 30%, which could achieve lower pressure drop and shorter separation time.

W3P.131 TRAPPING OF CELL-LADEN HYALURONIC ACID-ACRYLAMIDE HYDROGEL DROPLETS USING BULK ACOUSTIC WAVES

Anna Fornell[1], Carl Johannesson[2], Sean S. Searle[1,3], Axel Happstadius[2], Johan Nilsson[2], and Maria Tenje[1]
[1]Uppsala University, SWEDEN, [2]Lund University, SWEDEN and [3]National University of Singapore, SINGAPORE

We have developed a technical solution to trap cell-laden hydrogel droplets using bulk acoustic waves. The system is label-free, biocompatible, and operated in non-contact mode. Our results show that the droplets can be trapped for several hours under continuous flow. An application of the system is shown by performing on-chip staining of the encapsulated cells. The presented system opens up for new possibilities to perform multistep assays and long-term studies of the encapsulated cells.

Monday - Nanoscale Devices and Nanomaterials

M3P.132 CARBON NANOTUBE-BASED STRAIN SENSOR FOR EXCESSIVE SWELLING DETECTION OF LITHIUM-ION BATTERY

Woohyuk Choi, Youngno Seo, Kisoo Yoo, Tae Jo Ko, and Jungwook Choi
Yeungnam University, KOREA

This paper presents a carbon nanotube (CNT)-based strain sensor that can be mounted on a surface of lithium-ion battery for measurement of the battery swelling. The CNT sensor sensitively detects the irregular swelling of battery which can be caused by abnormal gas evolution and by increased temperature.

M3P.133 FABRICATION AND MORPHOLOGY REGULATION OF NANOWIRE FORESTS FOR TRANSPARENT SELF-DRIVING BIO-DETECTION DEVICES

Yudong Yang, Liang Chen, Haiyang Mao, Bo Gui, Shan Gao, and Weibing Wang
Chinese Academy of Sciences (CAS), CHINA

We fabricated transparent nanowire forests(NWFs) by using silane coupling agent as a promotor and regulator in a plasma repolymerization technique. The NWFs prepared in two-dimensional surface microchannels have a strong ability of liquid self-driving and biomolecule capturing. As is demonstrated, the NWF-based devices have much higher fluorescence intensity than conventional immunochromatographic test strips.

M3P.134 FLEXIBLE TACTILE AND SHEAR FORCE SENSING ARRAY BASED ON MULTILAYERED MXENE/CARBON NANOTUBE COMPOSITES

Shan Wang and Yao-Joe Yang
National Taiwan University, TAIWAN

This work presents a flexible tactile and shear sensing array by utilizing conductive multilayered MXene/carbon nanotube (CNT) composites as sensing material. Sandwich-like $Ti_3C_2T_x$ MXene/CNT sensing layers were realized by using the vacuum filtration technique to alternatively depositing layers of delaminated $Ti_3C_2T_x$ MXene flakes and multi-walled CNT. The direction and magnitude of the applied pressure can be estimated by the resistance change of the multilayer sensing cells.

M3P.135 HARNESSING POISSON EFFECT TO REALIZE TUNABLE TUNNELING NANOGAP ELECTRODES ON PDMS SUBSTRATES FOR STRAIN SENSING

Henry S.C. Yu, Giovanni Boero, and Jürgen Brugger
École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND

We demonstrated the fabrication and the electro-mechanical characterization of tunable tunneling nanogap electrodes (NGEs) on a PDMS substrate. Bottom-up capillary-assisted particle assembly in nano-scale traps is used to fabricate Au nanorod dimers as NGEs. The nanogap is tuned by the contraction due to the Poisson effect on a PDMS substrate. Moreover, finite element method simulations allow for optimizing the NGEs design for an application in highly sensitive and stretchable strain sensors.

M3P.136 NANOPARTICLE LOCALIZATION ON SOLID-STATE NANOPORES VIA ELECTROPHORETIC FORCE

Shiyu Li, Shuangshuang Zeng, Zhen Zhang, Klas Hjort, and Shi-Li Zhang
Uppsala University, SWEDEN

We present a versatile and facile method for precise localization of nanoparticles on solid-state nanopores surface-functionalized with carbon via electron beam induced deposition (EBID). For the first time, EBID of carbon is demonstrated to enable nanoparticle localization at solid-state nanopores. To avoid non-specific adsorption of nanoparticles on the surface, atomic layer deposited Al_2O_3 layer and phosphonate passivation are used.

M3P.137 WAFER-SCALE SELF ALIGNED FABRICATION OF NANOMETRIC CURVED TUNNELING JUNCTIONS

Yasser Pordeli, Bjorn T.H. Borgelink, Bernhard Y. Van der Wel, Erwin J.W. Berenschot, Tamer Dogan, Meint J. De Boer, Christiaan M. Bruinink, Harold J.W. Zandvliet, Han J.G.E. Gardeniers, and Niels R. Tas
University of Twente, THE NETHERLANDS

A self-aligned procedure for wafer-scale fabrication of curved tunneling junctions with nanometric lateral dimensions is introduced. Curved junctions were fabricated in the apex of inverted pyramidal pits created in a high density array of vertical silicon nano-pillars, by a combination of (concave) corner lithography, LOCOS and rapid thermal oxidation. The current densities of the functional curved MIS-junctions based on a 2.50 nm tunneling oxide layer are in the theoretically expected range.

Tuesday - Nanoscale Devices and Nanomaterials

T3P.131 ACOUSTIC ACTUATION OF SUSPENDED GRAPHENE FOR LINEAR EXCITATION OF 2D NEMS

Muhammad Faizan[1], Marsha M. Parmar[1], Philip X.-L. Feng[2], and Luis Guillermo Villanueva[1]
[1]École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND and [2]Case Western Reserve University, USA

In this paper, we present the fabrication of on-chip piezoelectric acoustic actuation for 2D materials. Acoustic actuation is achieved at device level through patterning of Aluminum nitride thin film at wafer scale. In electrostatic actuation we observe nonlinear damping where as in acoustic actuation we observe linear damping of graphene resonator. We also report the acoustic actuation technique to be less dissipative.

T3P.132 BIONANOSCAFFOLDS-ENABLED NON-WETTING SURFACES FOR ANTIBIOFOULDING APPLICATIONS

Sangwook Chu, Ishita Shahi, Ryan C. Huiszoon, James N. Culver, and Reza Ghodssi
University of Maryland, USA

We present Tobacco mosaic virus (TMV)-assisted formation of non-wetting polymeric surfaces displaying excellent antibiofouling performance. In a static 48-hour biofilm growth experiment, the TMV-based superhydrophobic surfaces, showing ~180º contact angle with no surface pinning in droplet bouncing experiments, resulted in a 6-fold less adherent biofilm on the surfaces compared to the planar counterparts, most likely attributed to the extreme non-adherent property and complex surface morphology.

T3P.133 EFFECT OF BUILT-IN STRESSES ON DEFECTS OF GRAPHENE BASED GAS SENSORS

Kai-Ming Hu[1], Kun-Chao Bai[2], Han Yan[1], Bo Peng[1], and Wen-Ming Zhang[1]
[1]Shanghai Jiao Tong University, CHINA and [2]National Nature Science Foundation of China, CHINA

It is of great interest to link Raman scattering to the properties of disorders in graphene membranes, which provides an effective method to probe the atomic scale defects. An interesting phenomenon, intensity ratios between D mode and G mode increase around the micro-wells, is observed in defective graphene sensors. The underlying mechanism is that the built-in stress provides the energy for the defect propagation of stretched graphene.

T3P.134 FABRICATION OF HIGH EFFICIENCY CARBON NANOTUBE THIN FILM HEATER BY SIMPLE SPRAY COATING & SUBSTRATE SHRINKAGE METHOD

Jeonhyeong Park, Ilryu Jang, and Hoe Joon Kim
Daegu Gyeongbuk Institute of Science and Technology (DGIST), KOREA

We present a high-efficiency thin film heater based on spray coated carbon nanotubes (CNTs). To enhance the device performance and control the junction densities, we implement the substrate shrinkage method by thermal treatment. Our results show that the shrunk thin film heater consumes much less voltage to reach the same temperature. In addition, we show the ability to control directionality of crumpled CNTs, allowing the local heating of the device.

T3P.135 FORMALDEHYDE GAS SENSOR BASED ON HYBRID FILM: GRAPHENE/ENZYME

Jungyoon Kim and Tianhong Cui
University of Minnesota, USA

This paper presents a tiny and cheap formaldehyde gas sensor. We used the hybrid film that consists of Chemical Vapor Deposition graphene and formaldehyde dehydrogenase. The new graphene-based gas sensors very quickly respond with formaldehyde gas. The sensor also shows the response with a low concentration of formaldehyde gas at ppb level. It also has a great selectivity for the formaldehyde gas because it is based on the enzymatic reaction.

T3P.136 ROLE OF CONTACTS IN CARBON NANOTUBE GIANT PIEZORESISTIVE SENSORS

Simon Böttger[1], Christian Wagner[2], Florian Lorkowski[1], Martin Hartmann[1], Georg Heldt[1], Jörg Schuster[1,3], Danny Reuter[1,3], and Sascha Hermann[1]
[1]Chemnitz University of Technology, GERMANY, [2]Helmholtz-Zentrum Dresden-Rossendorf, GERMANY and [3]Fraunhofer Institute for Electronic Nano Systems (ENAS), GERMANY

From the perspective of wafer-level integration technologies, this work presents theoretical and experimental insights on fundamental device properties of single-walled carbon nanotubes (SWCNTs) based giant piezoresistive transducers. The role of contacts in such devices and their contribution to a significant tunneling-related sensitivity enhancement is discussed. Moreover, perspectives for forthcoming sensor generations exposing operation regimes beyond intrinsic sensitivity are revealed.

Wednesday - Nanoscale Devices and Nanomaterials

W3P.132 EFFECT OF ATOMIC LAYER ETCHING ON RESIDUAL STRESS OF Al_2O_3 ALD ULTRA-THIN FILM SUSPENDED STRUCTURES

Emanuele Sortino[1], John P. Houlton[1], Jonas C. Gertsch[1], Omkar D. Supekar[1], George D. Skidmore[2], Steven M. George[1], Charles T. Rodgers[1], and Victor M. Bright[1]
[1]University of Colorado, USA and [2]Leonardo DRS, USA

This paper presents the first study of how ALE affects the residual stress in suspended ALD structures. Brownian motion of micromachined ALD resonators was measured using an optical interferometer before and after ALE processing. Experimental resonance frequencies were compared with FEM simulations to estimate the residual stress in the suspended structures. Results shows that ALE can be used to remove high stressed nucleation and coalescence regions in free standing structures.

W3P.133 FEW-LAYER $MoTe_2$ SUSPENDED CHANNEL TRANSISTORS AND NANOELECTROMECHANICAL RESONATORS

Xia Liu, Arnob Islam, and Philip X.L. Feng
Case Western Reserve University, USA

We report on the first demonstration of few-layer molybdenum ditelluride (MoTe2) suspended channel transistor (SCT) and nanoelectromechanical resonator operating at high frequency (HF) regime. The passivation of MoTe2 resonator using hexagonal boron nitride (h-BN) essentially creates h-BN/MoTe2 heterostructure bimorph. Moreover, we investigate the frequency tuning of the resonator and observe resonance frequency tuning, $\Delta f/f \approx 13\%$ by varying gate voltage from 0 to -16V.

W3P.134 HIGH SENSITIVE FLEXIBLE-BASED SINGLE-WALL CARBON NANOTUBES THERMAL SHEAR STRESS SENSOR FOR UNDERWATER APPLICATIONS

Wei Gao, Binghe Ma, Jian Luo, and Jinjun Deng
Northwestern Polytechnical University, CHINA

We develop a high sensitive polyimide-based single-walled carbon nanotube (SWCNT) thermal shear stress sensor for underwater applications with the sensitivity improving four to five times than typical Ni thermal sensor. To improve the temperature coefficient of resistance (TCR) of the sensor, vacuum thermal annealing is conducted. The TCR of the thermal sensor can be nearly 10000ppm/°C, which is the highest value of thermal sensor used for fluid measurements.

W3P.135 MOSAIC-LIKE MONOLAYER RGO/AG FILM VIA ULTRAFAST TWO-DIMENSIONAL ASSEMBLY FOR HIGH PERFORMANCE ROOM-TEMPERATURE GAS SENSOR

Xinyan Jia, Bingmeng Hu, and Xiaohong Wang
Tsinghua University, CHINA

This paper present a novel room temperature NO_2 gas sensor based on the 2D precise ordered mosaic-like assembly of RGO/Ag composites. This design not only provides a large sensing area, but also contributes to fast response/recovery times at room temperature without heating or irradiation. The remarkable performance of the sensor, achieved with a facile fabrication process, has a significant influence on the future industrial gas sensing devices.

W3P.136 SILICON NANOPILLARS WITH ZNO NANORODS BY NANOSPHERE LITHOGRAPHY ON A PIEZORESISTIVE MICROCANTILEVER

Jiushuai Xu, Maik Bertke, Steffen Bornemann, Shinta Mariana, Changfeng Fan, Angelika Schmidt, Hutomo Suryo Wasisto, Andreas Waag, and Erwin Peiner
Technische Universität Braunschweig, GERMANY

This paper reports on the fabrication of 3D silicon nanopillars modified with ZnO nanorods (i.e., ZnO-NRs@Si-NPLs) on a piezoresistive Si microcantilever (MC) for sensing application. A monolayer-colloidal-crystal film of polystyrene nanoparticles was deposited and used as physical mask for cryogenic Si dry etching. Vertically aligned Si-NPLs were selectively etched on the MC backside. In addition, ZnO-NRs were grown in-situ on the Si NPLs resulting in a 3D ZnO-NRs@Si-NPLs on the MC backside.

Monday - Transducers with Soft, Flexible or Composite Materials

M3P.138 A FLEXIBLE HUMIDITY SENSOR USING CANDLE SOOT AS SENSITIVE MATERIAL

Guidong Chen[1,2], Yudong Yang[2], Haiyang Mao[2], Shan Gao[2], Jijun Xiong[1] and Weibing Wang[2]
[1]North University of China, CHINA and [2]Chinese Academy of Sciences (CAS), CHINA

In this work, a flexible humidity sensor using hydrophilic candle-soot as its humidity sensitive material is proposed. In a relative humidity range from 30 to 95%RH, such a sensor achieves sensitivity of 4.32MΩ/%RH and a response time of 0.5s. Besides, no distinct deterioration in performance is observed when the sensor is bent upward and downward to certain degree.

M3P.139 A MECHANICALLY FLEXIBLE APTAMER-BASED GRAPHENE NANOSENSOR FOR BIOMARKER MONITORING

Ziran Wang[1], Zhuang Hao[2], Xuezeng Zhao[2], and Qiao Lin[1]
[1]Columbia University, USA and [2]Harbin Institute of Technology, CHINA

We develop a mechanically flexible aptamer-based graphene field-effect transistor nanosensor. The device consists of a monolayer graphene lying on a polyethylene terephthalate film, which is 2.5 μm thickness. The device, by conforming to underlying surfaces of the human body, offers significant improvements in robustness and durability. The sensor offers specific and consistent response in the real-time detection of biomarkers with limit of detection down to 37 pM.

M3P.140 DEAP BASED ACTUATOR FOR TACTILE AND MICROFLUIDICS APPLICATIONS

Rui Zhu and Ulrich Mescheder
Furtwangen University, GERMANY

We present a novel DEAP (dielectric electroactive polymer) based actuators for the generation of refreshable 3D deformation shapes. The shape formation is obtained by controlled and multiple cooperative buckling behaviors of a PDMS strip-like membrane using patterned, isolated electrodes along the strip and applying an appropriate voltage to these electrodes. The size of the deformed surface can be scaled from some hundred micrometers to some centimeters.

M3P.141 FIBER-BASED PIEZORESISTIVE WEARABLE SENSOR FOR KNITTABLE TACTILE SENSING

Jingjing Zhao[1], Miao Chi[2], Yulin Fu[2], Ying Dong[2], Xiaohao Wang[1,2], and Liwei Lin[1,3]
[1]Tsinghua University, CHINA and [2]University of California, Berkeley, USA

We report a close fitting wearable piezoresistive sensor based on knittable composite coaxial fibers with carbon nanotubes and polyaniline. Benefiting from fiber structure, the sensor remains not only high detection performance but also perfectly integration properties. With the weaving feature, these fibers can be easily knitted into fabric to form sensor array to obtain multiple sites force measurement for tactile perception.

M3P.142 FULLY FDM 3D PRINTED FLEXIBLE CAPACITIVE AND RESISTIVE TRANSDUCERS

Xavier Aeby, Ryan van Dommelen and Danick Briand
École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND

This paper shows feasibility of Fully Fused-deposition-modeling (FDM) printed capacitive and resistive transducers processed in a single tool. It enables their cost-effective and simple processing, and provides a new approach for sensors manufacturing in 3D printed constructions. By printing FDM conductive and dielectric filaments, resistive thermal and capacitive force transducers were fabricated and applied as touch sensors.

M3P.143 IN-SITU LASER PROCESSING FOR 3D PRINTED MECHANICAL TRANSDUCERS

Ryan van Dommelen[1], Olivier Chandran[2], Sebastien Lani[2], and Danick Briand[1]
[1]École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND and
[2]Centre Suisse d'Electronique et de Microtechnique (CSEM), SWITZERLAND

We report on the development of Laser Processing (LaP) techniques wherein a digitally driven Laser is integrated into a printing platform and used to cure Direct Ink Writing (DIW) printed conductive inks. As well as planarize 3D-printed temperature sensitive thermoplastics. Enabling functional layers to be integrated into Fused Deposition Modelling (FDM) printed layers, which we applied to fabricate both capacitive and resistive mechanical sensors.

M3P.144 PARYLENE PHOTONIC WAVEGUIDES WITH INTEGRATED VERTICAL INPUT/OUTPUT PORTS FOR FLEXIBLE, BIOCOMPATIBLE PHOTONICS

Jay W. Reddy, Maya Lassiter, Ramgopal Venkateswaran and Maysamreza Chamanzar
Carnegie Mellon University, USA

We demonstrate, for the first time, the design, fabrication, and packaging of compact (5 μm - 30 μm) photonic waveguides in a flexible, biocompatible polymer platform (Parylene C and PDMS) integrated with laser diodes as implantable devices for sensing and stimulation applications. We demonstrate that embedded precisely-defined angled micromirrors can be implemented at the input/output ports for broadband light coupling, enabling high-resolution light-delivery in tissue

M3P.145 SELF-POWERED INTUITIVE CONTROL INTERFACE TOWARDS DIVERSIFIED GAMING, AI, AND ONLINE SHOPPING APPLICATIONS

Tianyiyi He, Zhongda Sun, Qiongfeng Shi, Minglu Zhu, Hao Wang, Jiahui Wang, Feng Wen, and Chengkuo Lee
National University of Singapore, SINGAPORE

We propose a minimalist design to balance the requirement on the full functionality and the simplified signal processing capacity of the Human Machine Interfaces. And we develop a wearable glove-based control interface based on the triboelectric nanogenerators as a new alternative technology for diversified applications including 2D control, 3D control, cursor control, and game control.

M3P.146 TINY, LIGHT-WEIGHT AND FLEXIBLE COLOR SENSOR BY COMBINATION OF SE/GA_2O_3 PHOTODIODE ARRAY AND FLUIDIC-PRINTED RGB FILTERS

Yusuke Adachi and Taizo Kobayashi
Ritsumeikan University, JAPAN

This study presents a p-Se/n-Ga2O3 heterojunction photodiode array which can detect light intensities corresponding to red, green and blue (RGB) spectral distribution by light illumination from backside of a transparent polyimide film through RGB filters. The flexible color sensor can be attached onto even non-flat surface such as cylindrical tubes. To realize this sensor, a combination of thin film growth processes and fluidic printing technology of color filters was successfully developed.

M3P.147 WATERPROOF, OMNIDIRECTIONALLY STRETCHABLE ELECTRONICS WITH MULTILAYER PATTERNS VIA RAPID, PHOTOLITHOGRAPHY-FREE FABRICATION

Renxiao Xu[1], Peisheng He[1], Mohan Sanghadasa[2], and Liwei Lin[1]
[1]University of California, Berkeley, USA and [2]US Army, USA

Rapid fabrication of stretchable electronics systems with multiple layers of complex patterns without lithography steps is demonstrated. A desktop vinyl cutter and a laser cutter are used as patterning tools. As a proof-of-concept, we fabricate a waterproof, omnidirectionally stretchable supercapacitor patch with four layers, each with a different pattern, which can maintain full electrochemical performances after >16 hours of immersion in water, and extreme folding and stretching deformations.

Tuesday - Transducers with Soft, Flexible or Composite Materials

T3P.137 3D-INTEGRATION OF PRINTED ELECTROCHEMICAL SENSORS IN PET MICROFLUIDICS FOR BIOCHEMICAL SENSING

Silvia Demuru, Rubaiyet Haque, Marc O. Joho, Angélique Bionaz, Peter Van Der Wal, and Danick Briand
École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND

We present a novel process for screen printed electrodes fabrication, functionalization and integration in a fully polyethylene terephthalate (PET) fluidics system for electrochemical analysis.

T3P.138 A FLEXIBLE TRANSDUCER FOR MULTIFUNCTIONAL PHYSIOLOGICAL DETECTION IN NEURAL SCIENCE

Zhejun Guo[1], Bowen Ji[1], Minghao Wang[1], Xiaolin Wang[1], Bing Yang[1], Wei Wang[2], and Jingquan Liu[1]
[1]Shanghai Jiao Tong University, CHINA and [2]Peking University, CHINA

We proposed a flexible transducer for neural science based on polyimide which can stimulate the neuron by electricity or light, record electrical signal, and detect the tissue temperature in the same time. Furthermore, platinum (Pt) black modified microelectrode site has an excellent neural recording ability compared with gold one.

T3P.139 ALL-INKJET PRINTING SENSOR DEVICE ON PAPER: FOR IMMUNOSENSORS APPLICATIONS

Miguel Zea[1,2], Ana Moya[1], Aimad Abrao-Nemeir[2], Juan Gallardo-Gonzalez[2], Nadia Zine[2], Abdelhamid Errachid[2], Rosa Villa[1], and Gemma Gabriel[1]
[1]Instituto de Microelectronica de Barcelona, SPAIN and [2]Institut des Sciences Analytiques (ISA), Lyon, FRANCE

A novel flexible, low-cost and miniaturized paper-based transducer has been developed. It consist of an array of three microelectrodes where, the working and counter microelectrodes were easily printed using a gold nanoparticle ink. Using the transducer we developed an immunosensor against cortisol. Microelectrode characterization showed an enhanced of the electrochemical active area and demonstrated to be highly sensitive toward cortisol in physiological range.

T3P.140 DEVELOPMENT OF A FLEXIBLE TACTILE SENSOR ARRAY FOR THREE-DIMENSIONAL FORCE DETECTION WITH HIGH SENSITIVITY

Xuguang Sun, Shuaikang Zheng, Chunkai Wang, Jianhai Sun, Jiamin Chen, Tong Li, Chunxiu Liu, and Ning Xue
Chinese Academy of Sciences (CAS), CHINA

We designed, fabricated and characterized a flexible tactile sensor array utilizing MWCNTs-PDMS nanocomposite for 3D force detection. Owing to the anomalous and porous surface structure, the sensor array shows high sensitivity in normal pressure and tangential force detection and sliding speed measurement when an object slides across the array.

T3P.141 FLEXIBLE ELECTRET GENERATOR FOR SELF-POWERED METAL CATHODIC PROTECTION

Junwen Zhong and Liwei Lin
University of California, Berkeley, USA

We develop a self-powered metal cathodic protection strategy based on flexible electret generator. Innovative claims include:(1) a generator produced peak output power of about 450 μW, simultaneously having excellent output stability;(2) the excellent power generation ability was visually demonstrated by lightening up 28 blue LEDs;(3) the metal corrosion rate was reduced by 245% with the protection from generator.

T3P.142 HIGHLY STRETCHABLE KIRIGAMI STRUCTURE WITH INTEGRATED LED CHIPS AND ELECTRODES FOR OPTOGENETIC EXPERIMENTS ON PERFUSED HEARTS

Yusuke Morikawa[1], Suleman Ayub[2], Oliver Paul[2], Takeshi Kawano[1], and Patrick Ruther[2]
[1]Toyohashi University of Technology, JAPAN and [2]University of Freiburg, GERMANY

We propose a highly stretchable Kirigami device comprising μLED chips and electrodes for optophysiological experiments. The device is intended for the treatment of heart diseases such as ventricular arrhythmias. In contrast to the electrical stimulation using implantable defibrillation systems, optogenetic treatment is expected to reduce the severe side effects. In addition, the Kirigami device achieves the intimate integration to the biological tissue due its high stretchability.

T3P.143 KIRIGAMI CROSS-SHAPED 3D BUCKLING ACTIVE SENSOR FOR DETECTING STRETCHING AND BENDING

Liming Miao, Ji Wan, Hang Guo, Haobin Wang, Yu Song, Xuexian Chen, and Haixia Zhang
Peking University, CHINA

We develop a novel cross-shaped 3D buckling strain sensor based on PDMS substrate for detecting stretching and bending. Using pre-stretched PDMS, cross-shaped PI film with conductive silver paint as a 2D precursor can pop up as a dynamic 3D structure and possesses capacitive effect and triboelectric effect under different stretching and bending, which can detect stretching directions, strain value, bending axis direction and radius of curvature simultaneously.

T3P.144 PIS: WEARABLE PEDAL IONTRONIC SENSING FOR ARTERIAL PULSES AND MUSCULAR ACTIVITIES

Zhichao Zhang[1], Zijie Zhu[2], Ben Bazor[2], SueBin Lee[1], Zhi Ding[1], and Tingrui Pan[1]
[1]University of California, Davis, USA, and [2]TacSense Inc, USA

We first introduce a foot-based wearable system named Pedal Iontronic Sensing (PIS) which can both acquire body vital signals and track pedal muscular motions. Such system has been seamlessly integrated into a shoe format by constructing a highly sensitive and flexible pressure sensing array with the novel iontronic sensing principle. We have successfully illustrated that PIS can capture high-definition peripheral arterial pulse waveforms and track individual pedal tendon activities.

T3P.145 STIMULI-RESPONSIVE STRUCTURAL COLOR HYDROGEL MICROBEADS FOR WEARABLE BIOMETRIC SENSORS

Mio Tsuchiya[1], Yuta Kurashina[2], and Hiroaki Onoe[1]
[1]Keio University, JAPAN and [2]Tokyo Institute of Technology, JAPAN

This paper describes stimuli-responsive structural color microbeads as sensing elements for wearable biometric sensors. We solved the angle dependence of structural color by arraying spherical microbeads in a wearable device. For proof-of-concept, we prepared temperature responsive structural color microbeads and confirmed those microbeads array has no angle dependency. This is indicated that our sensor design is suitable for practical uses of structural color based eye recognizable sensors.

T3P.146 VACUUM POWERED PNEUMATIC ACTUATOR FOR WEARABLE ROBOTS BY THE KIRIGAMI OF POLYMERIC FILMS

Jiaming Liang[1], Yichuan Wu[1], Huiwen Kan[1], Renxiao Xu[2], Zhichun Shao[2], Wenying Qiu[1], Tao Jiang[1], Mingjing Qi[3], Min Zhang[1], Liwei Lin[2], and Xiaohao Wang[1]
[1]Tsinghua University, CHINA, [2]University of California, Berkeley, USA, and [3]Beihang University, CHINA

This paper reports a soft thin sheet vacuum powered pneumatic actuator design for wearable robotics for the first time. Three distinctive advancements have been achieved: (1) lightweight soft thin sheet kirigami structures design to generate bending and twisting movements; (2) capable of generating shape morphing of the cloth when attached on the surface; (3) transform into vacuum powered pneumatic soft crawling micro robot when detached from the cloth.

Wednesday - Transducers with Soft, Flexible or Composite Materials

W3P.137 A DISTRIBUTED 3D FORCE SENSOR FOR DETECTING INSECT MOTION BY OPTICALLY EVALUATING DEFORMATION OF MICROSCALE GRID PATTERN INSCRIBED ON A FLEXIBLE HYDROGEL SHEET

Masato Suzuki, Tomokazu Takahashi, and Seiji Aoyagi
Kansai University, JAPAN

To measure microscopic force (>[1] mN), a distributed force sensor made of transparent flexible sheet is proposed. Inside the sheet, grid pattern of microscale pitch is inscribed. Distributed force is obtained by optically evaluating the deformation of grid pattern. The force not only in vertical but also horizontal direction with respect to the sensor surface can be detected, i.e., it is [3] axis sensor. The force given by a mosquito leg was able to measure by the developed sensor.

W3P.138 ADVANCED 3D MORPHING TRANSDUCERS BY SMART HYDROGEL PATTERNING

Cong Wang[1], Sreepathy Sridhar[1], Jonathan G. Terry[2], Ansu Sun[1], Zhenghong Li[3], Haibao Lv[3], Ben B. Xu[1], and Yifan Li[1]
[1]Northumbria University, UK, [2]University of Edinburgh, UK, and [3]Harbin Institute of Technology, CHINA

We demonstrate a unique way of creating heterogeneous layered structures of soft functional materials for advanced transducerapplications. Hydrogel droplets with different composites were patterned by a "two-parallel plate" configuration used in microfluidicsapplications. Resulted heterogeneous layered structures of hydrogel were created, generating reconfigurable 3D (3-dimensional) deformation responding to discrete levels of stimulation inputs.

W3P.139 CONTROLLABLE NONLINEAR EFFECT FOR STABLE AND BROAD BANDWIDTH PIEZOELECTRIC ENERGY HARVESTER

Zhiran Yi[2], Xiaoxue Dong[1], Wenbin Zhang[1], Yingwei Tian[1], Lingchao Kong[1], Jingquan Liu[1], Ruihong Liang[2], and Bin Yang[1]
[1]Shanghai Jiao Tong University, CHINA and [2]Chinese Academy of Sciences (CAS), CHINA

This paper reports a buckled-bridge vibration energy harvester based on the thinned piezoelectric thick film. Through controlling the buckled angle, a broadband piezoelectric energy harvester (PEH) with a hardening or softening nonlinear effect can be obtained. A promising conception is demonstrated by integrating the two different nonlinear mechanism modules into one harvester to realize an ultra-broad bandwidth piezoelectric vibration energy harvester.

W3P.140 ENHANCEMENT OF PEDOT:PSS SEEBEK COEFFICIENT USING CARBON-QUANTUM-DOT-BASED NANOCOMPOSITE MATERIALS: APPLICATION TO INKJET PRINTING ON FLEXIBLE SUBSTRATE

Dimitris Barmpakos[1], Apostolos Segkos[1], Christos Tsamis[1], and Grigoris Kaltsas[2]
[1]National Centre for Scientific Research (Demokritos), GREECE and [2]University of West Attica, GREECE

This work presents the enhancement of PEDOT:PSS Seebeck coefficient with Carbon-Quantum-Dot-based nanocomposite material (CQDnm) for inkjet printing on flexible substrate. As it was experimentally extracted, polymer-filler ratio did not affect material printability, allowing for comparing thermovoltage generation for 0, 5, 10 and 20% PEDOT:PSS/CQDnm printed geometries on polyimide. A Seebeck coefficient improvement of 51.7% (18.51 to 28.0 μV/K) was achieved when filling PEDOT:PSS with 20% CQDnm.

W3P.141 FLEXIBLE ORGANIC ELECTROCHEMICAL TRANSISTOR WITH FUNCTIONALIZED INKJET-PRINTED GOLD GATE FOR BACTERIA SENSING

Silvia Demuru[1], Alexis Marette[2], Wafa Kooli[2], Pilar Junier[2], and Danick Briand[1]
[1]École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND and [2]University of Neuchatel, SWITZERLAND

We show for the first time organic electrochemical transistor (OECT) fully printed on flexible foil and integrating a gold gate. The latter can be selectively functionalized for bio-chemicals sensing, which has been demonstrated here for bacteria detection.

W3P.142 IN-PROCESS AND IN-USE MODULATION OF SENSITIVITY AND SENSING RANGE FOR CMOS-MEMS TACTILE SENSOR WITH DIELECTRIC PDMS NANOCOMPOSITE

Wei-Cheng Lai, Ming-Yi Lin, Ya-Chu Lee, and Weileun Fang
National Tsing Hua University, TAIWAN

This study presents a CMOS-MEMS tactile sensor fill-in with dielectric PDMS nanocomposite to batch fabricate and modulate the sensing range and sensitivity. Merits of the sensor are: In-process batch selective modulation, tactile sensors with different sensing ranges and sensitivities are batch fabricated simultaneously. In-use modulation, the sensing range and sensitivity of each tactile sensor can still be modulated after the curing process.

W3P.143 LARGE SCALE ARRAY VISIBLE-INFRARED CONVERTER BASED ON FREE-STANDING FLEXIBLE COMPOSITE MICROSTRUCTURES

Lang Zhou[1], Zhuo Li[1], Defang Li[1], Chang Xu[1], Yanze Gao[1], Jinying Zhang[1], Xin Wang[1], Suhui Yang[1] and Keyi Wang[2]
[1]Beijing Institute of Technology, CHINA and [2]Macro-Micro Electronics Technology Co., Ltd., CHINA

We develop a transparent flexible microstructured polymer array combined with patterned nano-forest of metallic film. The proposed composite configuration exhibits reduced reflection and enhanced absorption in a broadband visible spectrum. It contributes a simple, low-cost and effective approach to obtain a soft visible-infrared converter with a large scale array.

W3P.144 REINFORCEMENT DESIGN FOR NEWTON-LEVEL HIGH FORCE GENERATED BY BENDING MOTION OF SOFT MICROACTUATOR

Hirotoshi Kosawa and Satoshi Konishi
Ritsumeikan University, JAPAN

We report on a soft microactuator for high bending force generation. We have succeeded in demonstrating the Newton-level high force generation by the bending pneumatic balloon actuator (PBA) made of polymer. Novel reinforcement design of PBA using the combination of ribs and a conversion film will be described and followedby characterization of the device. Demonstrated soft microactuator with 16mm × 40mm × 850μm can generate more than 1.5N at 60kPa.

W3P.145 STRAIN-INSENSITIVE SOFT PRESSURE SENSOR FOR HEALTH MONITORING APPLICATIONS USING 3D-PRINTED MICROCHANNEL MOLD AND LIQUID METAL

Kyuyoung Kim[1], Jungrak Choi[1], Yongrok Jeong[1], Minseong Kim[1], Incheol Cho[1], Seunghwan Kim[1], Yongsuk Oh[2], and Inkyu Park[1]
[1]Korea Advanced Institute of Science and Technology (KAIST), KOREA and [2]Northwestern University, USA

Here, we introduce liquid metal-based soft pressure sensor using a 3D-printed mold with high sensitivity, strain-insensitivity, a stable sensor signal, and robust interconnection. The sensitivity of the pressure sensor has enhanced by the integration of 3D-printed microbump into the elastomer and the strain-insensitivity is achieved by the serpentine patterns of the microchannel. We have implemented the pressure sensors for wearable health monitoring applications.

W3P.146 THIN-FILM SILICON RESONATORS ON ULTRA-FLEXIBLE 10 MICROMETER-THICK POLYIMIDE SUBSTRATES

Tiago G. Pestana[1], Rui M.R. Pinto[1], Rosana A. Dias[3], Marco Martins[3], Virginia Chu[1], João Gaspar[3], and João P. Conde[1,2]
[1]INESC Microsytems and Nanotechnologies, PORTUGAL, [2]Instituto Superior Técnico, PORTUGAL, [3]International Iberian Nanotechnology Laboratory (INL), PORTUGAL

We present thin-film silicon microresonators fabricated on 10 μm-thick polyimide. This work includes the characterization of the devices at resonance, the study of the MEMS' electronic addressing when the substrate is bent to several radii of curvature and FEM simulations of the devices' frequency response. These MEMS preserve the mechanical properties of Si in ultra-flexible substrates and could potentially be applied to wearables, distributed sensing and interfacing with the human body.

W3P.147 WEARABLE TEXTILE-BASED GLUCOSE FUEL CELL USING MOSITURE MANAGEMENT FABRICS FOR IMPROVED & LONG-TERM POWER GENERATION

Cong Wang[1], Euijin Shim[2], Hyung-Kwan Chang[1], Nuree Lee[1], Zonglin Mu[1], Hye Rim Kim[2], and Jungyul Park[1]
[1]Sogang University, KOREA and [2]Sookmyung Women's University, KOREA

We proposed a wearable textile-based glucose fuel cell using moisture management fabrics (MMF). MMF is composed of polyester with modified cross-sectional shapes for quick water absorbing and wicking, so naturally continuous flow with high flow rate can be induced and results in improved and long-term power generation. Owing to low-cost and scalable fabrication process, it can be easily integrated into clothes to utilize human body fluid to generate energy for wearable devices.